PATTERNS OF INHIBITORY CONTROL AND SOCIOEMOTIONAL DEVELOPMENT: A MULTIMODAL EXAMINATION IN EARLY AND MIDDLE CHILDHOOD

by

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ABSTRACT

Background: Emotional and behavioral regulation are at the core of children's health and well-being. Limited work has examined the constellation of children's internal (i.e., physiological) and external (i.e., behavioral) regulation during situations that challenge children's ability to delay gratification. Factors influencing how children view their own regulation difficulties are not well-known.

Methods: Study 1. Motor activity, vocalizations, and anticipation during Mischel's Delay of Gratification Task were measured in 133 5-year-old children. Latent modelling characterized children into regulation classes and examined relationships with delay ability. **Study 2.** Heart rate and respiratory sinus arrhythmia (RSA) during the task served as indicators of physiological regulation. Multivariable regression and latent models analyzed concurrent physiological and behavioral regulation. **Study 3.** Mothers, teachers and children from 67 families completed the Strengths and Difficulties Questionnaire (SDQ), a measure of childhood behavioral and emotional regulation in middle childhood. Multivariable regression models examined concordance among reporters and the impact of maternal psychological distress on children's regulation.

Results: Children clustered into three regulation groups: *passive* (low motor/vocal, moderate anticipation); *active* (moderate motor/vocal, high anticipation); and *disruptive* (high on all indicators). Children in the *active* class were less likely to delay gratification compared to the *passive* and *disruptive* classes (Study 1). Children who delayed gratification had less increase in heart rate coupled with decrease in RSA during the delay task; physiological regulation was particularly important for children in the *active* class (Study 2). When rating themselves,

children reported more difficulties than mothers and teachers. Those with more psychologically distressed mothers rated themselves as having more difficulties, as did their teachers (Study 3).
Conclusions: Children whose anticipation levels exceeded their level of self-regulatory strategies struggled to delay gratification. Children exhibiting physiological flexibility to modulate anticipation during the task, even in group that struggled to delay, were able to successfully delay. Physiological indicators provide a window into internal adaptive regulation. Children reported having socioemotional difficulties that were unobserved by mothers and teachers. This suggests that the use of proxy informants, typically parents, alone may not suffice in middle childhood. Examining multiple components of regulation can provide insight into children's mental health and well-being.

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CHAPTER ONE

Introduction, Significance and Study Aims

1.1 Introduction and Significance

Placing focus on examining environmental, social and biological systems has bolstered the understanding of early childhood roots of lifelong physical and mental health. Emotional and behavioral regulation is at the crux of children's developmental and psychological well-being. Such regulation is shaped by numerous internal and external factors including genetics, social support, early life experiences, and temperament, with some trajectories differing by child sex (McCarthy et al., 2015). Recently, findings from developmental science, specifically related to children's socioemotional well-being, have been translated into public health programs and policies such as integrative socioemotional learning programs in schools (Bailey et al., 2019; Durlak et al., 2011), early parenting and family-related interventions (Hastings et al., 2019; Lengua et al., 2007) and examining precursors to mental health outcomes by indexing behavioral and emotional difficulties (AAP, 2012). These advances are facilitated by integral developmental research such as behavioral and physiological correlates of self-regulation (Blair, 2002; Blair & Raver, 2015), the role of caregiver relationships on positive child development (Calkins & Fox, 2002), and links between early biobehavioral regulation and later socioemotional outcomes such as depression, anxiety, aggressiveness and poor inhibitory control (Anzman-Frasca et al., 2015; Halfon & Hochstein, 2002).

Research on the development of regulatory control has further garnered national interest with increased prevalence of early onset emotional, behavioral and developmental conditions, including attention-deficit/hyperactivity disorder (ADHD), depression, anxiety problems, and behavioral or conduct problems such as oppositional defiant disorder or conduct disorder (Bitsko et al., 2016). Typically, measurement of mental health symptomology surrounding socioemotional dysregulation is focused on adolescence. However, increasing evidence has suggested that precursors to pervasive mental health issues emerge much in earlier development (Ghandour et al., 2019; Ozonoff, 2015). Early detection of emotional and behavioral difficulties can help assure that children reach their developmental potentials. One such aspect that will be explored in this dissertation is the validity of children's self-reported emotional and behavioral difficulties in middle childhood.

Individual differences in development arise through intrinsic and extrinsic-dependent processes, specifically in the ways that individuals react or respond to external, day-to-day stimuli and stressors, or self-regulate. Self-regulation is understood as the mechanism by which thoughts, behaviors and emotions are processes, managed and expressed (Cox et al., 2010; Posner et al., 2014; Rothbart et al., 2011). Self-regulation involves both initiation and maintenance of responses and inhibitory undesired behaviors based on situational demands. The ability to regulate is considered as an essential pathway by which emotional, behavioral, social and learning-related factors, collectively referred to as socioemotional competencies, arise (Blair & Raver, 2015; Blair & Razza, 2007; Eisenberg et al., 2009; Espy et al., 2011; Sethi et al., 2000). Regulation has been conceptualized as an adaptive system involving physiological, attentional, emotional, behavioral and cognitive domains that start to emerge early in infancy and continue to develop through dynamic patterns of person-context interactions (Bronfenbrenner, 1977; Eisenberg et al., 2009; Maniar & Zaff, 2011; Nigg, 2017).

Reflecting regulatory processes through measurement of physiological indicators is critical to the understanding of observable and unobservable components of child development; how the body detects, reacts, and adapts to challenges is fundamental and indicative of how external experiences “get under the skin” (Johnson et al., 2013). A large body of literature has provided links between psychophysiological indicators, and regulation of attention, emotion and social behaviors (Coulombe et al., 2019; Fox et al., 2006; Porges et al., 2007; van der Molen, 2000). Psychophysiological research focused on indexing children’s regulatory capacity has typically relied on the use of laboratory-based stimuli to elicit behavioral and physiological responses (Fox et al., 2006). Such methods provide a way for studying how external stimuli challenge children’s behavioral and physiological stress response systems. Physiological regulation and reactivity can reveal aspects of arousal, flexibility and adaptation to external perturbations that lead to a well-rounded picture of contributions to children’s development.

Characterizing early self-regulatory strategies, physiological reactivity, and measurement methods through developmental periods facilitates disentangling the complex nature of child development and provides insight to inform programs that support social and emotional development of children. There has been increased awareness within public health on targeting programs, interventions and policies aimed at improving children’s self-regulation. This push has stemmed from substantive developmental evidence stating that the ability to self-regulate is foundational for life-long functioning and well-being (Shonkoff & Garner, 2012). Therefore, examining multi-level factors fundamental to regulation, such as biological susceptibility, behavioral expression and socioemotional competencies, can elucidate pathways to typical and atypical development influencing children’s mental health and well-being.

The goal of this dissertation is to examine processes underlying children’s regulation using two different approaches: 1) a laboratory-based delay of gratification task; and 2) multi-informant questionnaire-based assessments. The studies focus on evaluating internal and external patterns of regulation, behavioral expression and socioemotional competence with the following aims: 1) assess impulsigenic and volitional processes underlying regulation during a delay of gratification task in kindergarten aged children, 2) examine physiological correlates of regulation during the delay of gratification task, and 3) analyze the utility of a multi-informant approach to measuring emotional and behavioral difficulties in middle childhood.

1.2 Study Aims and Hypotheses

Aim/Manuscript 1: Explore children's spontaneous use and intensities of various self-regulatory strategies, such as motor activity and vocalizations, and levels of anticipatory behaviors during a standard Delay of Gratification task in 5-year-old children.

Hypothesis 1.1. Children who show low to moderate levels of motor activity (i.e., in seat, fidgeting), vocalizations (i.e., whispering, self-talk/distraction) and anticipation (i.e., attention away from reward) will be able to delay the full task time as compared to children who show high levels of these components.

Children are faced with many situations where they need to inhibit impulses and/or delay gratification. Prior research has indicated that children employ a range of spontaneous strategies for inhibitory control (Bialecka-Pikul et al., 2018; Rodriguez et al., 1989; Sethi et al., 2000; Supplee et al., 2011). Although inhibitory control is considered a hallmark of child development, many children have trouble expressing developmentally appropriate levels of controls. Lapses in inhibitory control have been related to a host of maladaptive outcomes in adolescence and even into adulthood (Anzman-Frasca et al., 2015; Eisenberg et al., 2001; Kochanska et al., 2000; Lengua, 2002). Motor activity and vocalizations examined in this study will provide insight into volitional, or voluntary, processes that children use to self-regulate/control impulses and delay gratification. Identifying anticipatory behaviors will help identify impulsigenic, or impulsive, processes at play during this task. In addition, the role of maternal and child characteristics relating to differences in inhibitory control strategies will be examined using samples of children from families who range from low to middle/high socioeconomic statuses.

Hypothesis 1.2. Motor activity, vocalizations, and anticipatory behaviors will cluster in distinct patterns of child inhibitory control capacity.

The balance between impulsigenic and volitional mechanisms will be examined using a person-centered approach. Although, to date, no study has examined the combined role of motor activity, vocalizations and anticipation during inhibitory control tasks using a latent variable approach, it is hypothesized that children will exhibit differing combinations of these measures to self-regulate when faced with an inhibitory control challenge. This hypothesis is supported by several studies that show multiple influential mechanisms for inhibitory control (Blair, 2002; Blair et al., 2011; McGuire & Kable, 2013; Neuenschwander & Blair, 2017; Sethi et al., 2000).

Hypothesis 1.3. Children who use moderate inhibitory control strategies will be able to delay more successfully as compared to children who exhibit low or higher levels of these constructs.

Prior work has suggested an inverted-U relationship between impulsigenic/volitional processes and task performance (Duckworth & Steinberg, 2015; Yerkes & Dodson, 1908). Therefore, it is hypothesized that children who utilize self-regulatory behaviors, and who are able to modulate their arousal/anticipation, will be able to successfully delay as compared to children who are more driven by impulsigenic processes. Differences in inhibitory control capacity by maternal and child characteristics, specifically child sex, is hypothesized based on literature surrounding sex differences in neuro-attentional processes related to inhibition (Liu et al., 2013; Rubia et al., 2013; Spielberg et al., 2015).

Aim/Manuscript 2*:* Assess physiological regulation underlying children's inhibitory control using heart rate and respiratory sinus arrhythmia (RSA) measures during a standard Delay of Gratification Task in children 5 years of age.

Hypothesis 2.1: Children who delay the full task time will have differentiating levels and patterns of heart rate and RSA as compared to children who do not delay the full delay of gratification task time.

Autonomic nervous system functioning, indexed here through heart rate and RSA, a measure of parasympathetic control of the heart, is commonly implicated in self-regulation and socioemotional capacity due to its interconnectedness with limbic brain systems. Heart rate and RSA appear to be physiological antecedents of inhibitory control, with changes in heart rate and RSA closely tied to adapting to one's environment, sustaining attention, and employing effortful control (Sturge-Apple et al., 2016). Most research has focused on examining mean levels of heart and RSA pre-challenge/stressor and in response to challenges/stressor. Limited work has examined patterns of heart and RSA during the delay of gratification task. Therefore, direction and magnitude of differing HR and RSA patterns during delay task are uncertain.

Hypothesis 2.2: Children with lower pre-task heart rate/higher RSA will be able to delay more successfully than children who have higher pre-task heart rate/lower RSA. Children with less increase in heart rate/decrease in RSA to task will be able to delay more successfully than children whose heart rate and RSA substantially increase to task.

Research has indicated that higher levels of basal (resting) RSA and increased vagal suppression (or decrease in RSA relative to baseline/resting RSA) are associated with better performance on self-regulatory tasks, including those that measure inhibitory control (Hinnat & El-Sheikh, 2009). Heart rate responses during inhibitory control tasks differ based on level of children's impulsivity and activation of attentional processes, as heart rate reflects both parasympathetic regulation as well as sympathetic regulation. Findings on direction and magnitude of relations between heart rate and inhibitory control are inconclusive. RSA reflects the co-regulation of heart rate and respiration through parasympathetic influences; this co-regulation informs the direction of expected HR associations for this hypothesis.

Hypothesis 2.3: Heart rate and RSA will moderate the relationship between inhibitory control classes and delay ability such that children whose inhibitory control strategies helped them delay will have less heart rate and RSA change as compared to children who had ineffective inhibitory control strategies.

This hypothesis is largely motivated by research briefly highlighted for Hypothesis 2.2. To date, there is limited research on observed behavioral and physiological regulation in tandem during delay tasks. One study examined concurrent heart rate and electrodermal activity and indexed children's difficulty delaying, but only among children who delayed the full task time (Wilson et al., 2009). Less is known about co-occurring behavioral manifestations of inhibitory control and physiological regulation.

Aim/Manuscript 3: Compare and contrast maternal, teacher and child-self reported difficulties in behavioral and emotional regulation in middle childhood (8-12 years) using a well-validated measure, the Strengths and Difficulties Questionnaire (SDQ).

Hypothesis 3.1: There will be modest concordance between informants such that mothers and children will report more similarly as compared to mothers and teachers and children and teachers.

There have been two meta-analyses regarding multi-informant reports, based on studies conducting from 1967 to 2014 (Achenbach et al., 1987; De Los Reyes et al., 2015). These reviews found modest concordance (*M* r = .28) across informants (i.e., parents and children or parents and teachers) and higher concordance between reporters when rating externalizing behaviors as compared to internalizing behavior. Most studies included in these reviews are limited to child self-report measures in adolescence, despite evidence that children as young as age 5 can reliably report on their behaviors and feelings (Riley, 2004). This dissertation adds to the literature base by examining the utility of child self-report in middle childhood.

Hypothesis 3.2: Maternal and child characteristics, specifically maternal psychological distress, will play a role in explaining discordance between mother, child and teacher reports

Sociodemographic, family and child factors have been repeatedly examined with respect to multi-informant reports. These can include child age, child sex, family socioeconomic status, maternal characteristics (Duhig et al., 2000; Harvey et al., 2013; van der Veen-Mulders et al., 2017), maternal mental health symptomology (Madsen et al., 2019), observability of behavior characteristics (Vierhaus et al., 2018), and cultural and social aspects (Rescorla et al., 2007). Specifically, maternal depression and anxiety symptoms are typically associated with inflation in reporting child problem behaviors (e.g., (De Los Reyes et al., 2015; Gartstein et al., 2009; Madsen et al., 2019; Monti & Rudolph, 2017; Muller et al., 2011; Ringoot et al., 2015). It is hypothesized that selected maternal and child characteristics and maternal psychosocial distress will explain significant variance between maternal, teacher and child self-reports.

Hypothesis 3.3: Observability of behaviors will explain any differences seen between reporters, such that reporters will agree more on externalizing behaviors and disagree more on internalizing behaviors

A relationship between observability of behaviors, that is the degree to which behaviors are externally expressed, and multi-informant agreement has been proposed repeatedly, however empirical evaluations of this relationship are limited. The few studies that have examined "observability" of behaviors in multi-informant concordance/discordance have shown higher multi-informant correlations when reporting on externalizing behaviors as compared to internalizing behaviors (Achenbach et al., 1987; Cleridou et al., 2017; De Los Reyes et al., 2015; Vierhaus et al., 2018). Therefore, it is expected that more observable behaviors (i.e. externalizing) will be concordant across reporters as compared to non-observable or internal rumination (i.e., internalizing).

1.3 Organization of Dissertation

This dissertation includes three separate empirical manuscripts, intended for submission to journals upon modification, and supportive chapters that introduce the dissertation, present the theoretical framework and existing knowledge used to guide the study aims, describe study methods and designs, and discuss the conclusions and implications of the findings.

This chapter (Chapter 1) presented the study aims, hypotheses and overarching significance of this dissertation work. The second chapter focuses on background information for socioemotional and physiological concepts examined in this dissertation, key findings from the literature that informed the study aims and a theoretical framework that motivated the study aims. Literature relating to specific aims and hypotheses will be reviewed in the respective manuscript chapters, therefore Chapter 2 only provides a broad review of key concepts. Chapter 3 provides descriptions of the study designs, measures and methods that form the basis for Aims 1 and 2 (Manuscripts 1 and 2) and details on de novo data collection for Aim 3 (Manuscript 3). Chapter 3 also provides details on sample selection and statistical analysis by study aim/manuscript; study design, measures and methods are re-iterated in the respective manuscript chapters. Chapters 4, 5, and 6, each contain draft manuscripts, based on the 3 Aims, including related literature reviews and discussions of strengths and limitations for each study. The final chapter ties together results from the three manuscripts and discusses the conclusions and implications of the study findings.

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CHAPTER TWO

Background and Theoretical Basis

2.1 Background

Self-Regulation and Child Development

Self-Regulation Overview

Self-regulation is understood as the internal mechanism by which thoughts, behaviors and emotions are processed and managed in a systematically orchestrated manner to achieve a particular goal (Cox et al., 2010; Posner et al., 2014; Rothbart et al., 2011). Individual differences in self-regulation and reactivity are considered to be the core facets of temperament. Reactivity refers to the strength and expression of emotional, attentional and motor responses, elicited by external stimuli (Rothbart, 1989). Self-regulation, on the other hand, is how one controls and manages their expression of emotions and behaviors. As such, self-regulation requires integration, management and execution of hierarchically organized set of functions that change across development in relation to interpersonal and social environments and experiences (Blair, 2002; McClelland & Cameron, 2012). This adaptive modulation of reactivity and emotional expression is mediated by neuroendocrine and physiological processes (Kelley et al., 2015; Posner & Rothbart, 2000). The ability to self-regulate is an essential developmental task in early childhood; it is the basis for emotional (i.e., processing emotional arousal), behavioral (i.e., impulse control), social (i.e., maintaining relationships) and learning-related (i.e., attention regulation and shifting) factors, collectively referred to as socioemotional competencies (Blair & Raver, 2015; Blair & Razza, 2007; Eisenberg et al., 2009; Espy et al., 2011; Sethi et al., 2000).

Self-regulation processes exhibit plasticity over time and through dynamic patterns of person-context interactions, highlighting the importance of understanding longitudinal trajectories and socio-ecological influences on development of self-regulation and vulnerability (Bronfenbrenner, 1977; Eisenberg et al., 2009; Maniar & Zaff, 2011; Nigg, 2017). Contextual factors that may play a key role in development and trajectory of self-regulatory capacity include family, peer/school, and community influences. Self-regulation develops from birth with gradual accumulation of complex capabilities through the life course (Cox et al., 2010; Nigg, 2017; Posner & Rothbart, 2000). Some literature surrounding development of self-regulation has suggested early antecedents of regulatory behaviors starting as early as the fetal period (Conradt et al., 2015; DiPietro et al., 1996; Kelley et al., 2015; Mezzacappa et al., 2011). The development of external self-regulatory capabilities is paralleled with physical and neural development, with critical periods in early childhood (infancy to age 8 years) and adolescence (ages 12-19 years) (Cox et al., 2010; Nigg, 2017; Posner & Rothbart, 2000). Fewer studies have examined implications of self-regulation and socioemotional issues during middle childhood (ages 8-12). Despite significant evidence indicating childhood as an important time period for development and sustenance of self-regulation, gaps still remain in fully understanding the intersection between behavioral, emotional and physiological processes underlying self-regulation and socioemotional development.

Development of Self-Regulation

Calkins and Fox (2003) suggest a multi-level theoretical approach to understanding development of self-regulation during early childhood and later behavioral outcomes. This model presents an integration of skills that are developmentally ordered, such that the primitive level of physiological regulation (i.e. heart rate, adrenocortical activity) lays the foundation for development of attentional regulation (i.e. sustain focus, shift attention, inhibit actions), which in turn informs emotional (i.e. self-comforting, help seeking) and behavioral (i.e. managing frustration and/or fear) regulation. Children also begin to integrate control of attention, motor inhibitory control and vocal expressions, to moderate and manage impulsive reactions in order to accomplish important developmental tasks, such as delay gratification (Fox & Calkins, 2003). Regulatory processes, therefore, evolve into more complex and self-initiated practices over the course of child and adolescent development, with key inputs from social support and life experiences (Calkins & Fox, 2002). Caregiver-child relationships are at the core of early developmental processes (Leclere et al., 2014). The emotional experiences of infants are most commonly present during caregiver interactions. During infancy, successful self-regulation depends largely on caregiver awareness, flexibility and emotional expression, aiding in infant self-regulation (Calkins & Fox, 2002). Apart from caregivers tending to basic infant needs (i.e. feeding), the quality of caregiver-child relationships has implications for multiple facets of development such as self-regulation and socialization (Leclere et al., 2014). Atypical caregiver-child interactions have been associated with behavioral and affective developmental delays (Leclere et al., 2014).

Over the course of development, the capacity to independently self-regulate increases, first, regarding motor and affective behavior, as a function of supportive caregiving, and later as a function of voluntary and effortful control (Blair & Raver, 2012; Calkins & Fox, 2002; McClelland & Cameron, 2012; Posner & Rothbart, 2000; Rothbart et al., 2011). Successful development of self-regulation can be seen as a result of increasing control over attentional processes, behavioral expression and emotional arousal over time in response to day-to-day interpersonal and contextual stimuli all developing in parallel with autonomy (Calkins & Fox, 2002; Kochanska, 1997; Kochanska et al., 2001; McClelland & Cameron, 2012; Posner & Rothbart, 2000; Rothbart et al., 2003; Rothbart et al., 2011; Rothbart et al., 1992; Zucker et al., 2011). Through the course of development, the shift of external factors influencing self-regulatory capacity changes from caregiver-related input in infancy to larger social sphere influences, such as peers and community.

Neurological development in childhood allows for rapid learning, integrating multiple developmental systems including functional neural connectivity between motor, vocal and cognitive processes (Leisman et al., 2016). Such integration requires learning of sequential actions through external and contextual input, initially acquired during childhood and modified through experiential and formal education (Leisman et al., 2016). Therefore, parsing out the role of cognitive ability (behavior planning, executive functioning), motor activity (movement control), attentional processes (self-talk), and emotional expression over time are essential to understating children's development and use of self-regulatory strategies.

Inhibitory Control in Early Childhood

Inhibitory control, a component of self-regulation, is the ability to voluntarily coordinate behaviors to regulate emotions and modulate attention to inhibit a dominant or impulsive response (Rothbart et al., 2011; Rueda et al., 2005). Inhibitory control emerges between 6 and 12 months of age, paralleling maturation of attentional mechanisms in the brain (Kochanska et al., 2000). The ability to inhibit and modify actions in response to environmental changes and demands is a key aspect of goal-directed behavior (van de Laar et al., 2014). Therefore, the role of inhibitory control in learning ability, cognitive ability, motivational inhibition, and attentional inhibition is evident (Caswell et al., 2013; Ibbotson & Kearvell-White, 2015; Kochanska et al., 2000; Manfra et al., 2014; Morasch & Bell, 2011).

Dysregulated inhibitory control during childhood has been associated with impulsivity problems, attention deficit hyperactivity disorder (ADHD), and adjustment and conduct problems, even into adulthood (Anzman-Frasca et al., 2015; Caswell et al., 2013; Ibbotson & Kearvell-White, 2015). Children who have problems with inhibition tend to be impulsive, lack self-control, respond inappropriately, have trouble completing tasks and have trouble delaying gratification (Macdonald et al., 2014). Children who fail to develop inhibitory control in early mid-childhood often experience learning and social difficulties and are delayed to attain age-related developmental milestones (Macdonald et al., 2014). Thus, measuring processes involved in inhibitory control can provide insight into interventions aimed at self-regulation management to increase children's developmental potential.

Self-Regulation in Middle Childhood: A focus on emotion regulation

Emotional regulation plays a fundamental role in child development by influencing social competence, behavioral adjustment and later psychopathy. Achenbach and colleagues (1978) categorized emotional regulation into two well-known dimensions: internalizing and externalizing behaviors. Internalizing behaviors include seclusive and withdrawn behaviors, characteristic of anxiety and depressive disorders, while externalizing behaviors include aggressive tendencies and under-socialization, characteristic of oppositional defiant and conduct disorders (Achenbach, 1978; Kooijmans et al., 2000). Internalizing behaviors reflect an adaptation to environmental context that instigates internal distress while externalizing behaviors result in outward expression of distress and conflict with others (Agnes Brunnekreef et al., 2007). There is a large literature base that discusses internalizing and externalizing behaviors, early predictors, and physiological correlates, pointing to the complex etiology underlying trajectories of development (for review see (Achenbach et al., 2016). Some early contributors to disposition of internalizing and externalizing behaviors include peer relationships, parenting behaviors, socioeconomic status, co-occurring behavioral issues (i.e. ADHD), maternal mental health and biological vulnerabilities (Wang et al., 2018).

Sex differences in neurodevelopment and behavioral trajectories has been of interest since the late 1960s (McCarthy et al., 2015). Specific time periods, corresponding to socialization (i.e. school) and times of hormonal change (puberty), mark pronounced sex-specific differences in physiological, psychological and behavioral development. There is a well-established body of literature that also shows higher levels of impulsivity in boys than in girls, with implications for sex differences in related disorders such as ADHD, substance abuse disorders and conduct disorders (Rubia et al., 2013). On the other hand theories of social construction behind sex differences posit that girls are socially required and expected to inhibit maladaptive responses, therefore making acts of impulsivity and subsequent consequences deemed as more severe than when discussed for boys (Liu et al., 2013).

Sex differences in internalizing and externalizing behaviors are also well established (for review see (Martel, 2013)). Girls trend towards more internalizing symptoms and psychopathology, such and anxiety and depression, while boys are more prone to exhibit externalizing behaviors such as delinquency, aggression and conduct disorders (Hoffmann et al., 2004). Sex differences in internalizing and externalizing behaviors begin to emerge in childhood, become more pronounced during adolescence, which continue to manifest through adulthood (Hoffmann et al., 2004). The literature base identifies early adolescence as the ideal time period to study the emergence of sex differences in psychopathology. However, few studies have examined incremental trajectories of such behaviors longitudinally for girls and boys (Cotter et al., 2016).

Measurement of Inhibitory Control and Regulation

Children are faced with many situations where they need to suppress behaviors in order to resist impulsive actions and employ self-control. Many different measures of inhibitory control and self-regulation are used in the literature, each with its own advantages and limitations. Methods of assessment include parent or teacher reported questionnaires (i.e. Child Behavior Questionnaire), and direct assessment using behavioral tasks (i.e. Stroop Task, Go/No-Go task, computerized games, delay tasks). In this dissertation, processes underlying inhibitory control and regulation will be measured in two ways: during the laboratory-based Delay of Gratification task (Mischel et al., 1989) and child, mother, and teacher reports using the Strengths and Difficulties Questionnaire (SDQ). The Delay of Gratification Task (or delay task) measures a child’s ability to wait for a later reward, instead of taking the immediate and/or lesser reward—this construct is facilitated by self-regulatory strategies as well as impulse control management. The socioemotional constructs captured with the SDQ, such as emotional symptoms, hyperactivity, and conduct problems, are often used as a source to understand emotional and behavioral regulation in childhood (Theunissen et al., 2019).

Extensive research on the construct of delay of gratification has largely focused on one’s ability to delay versus not and subsequent behavioral implications. Little focus has been on how and why some children are able to delay gratification as compared to others (Wilson et al., 2009). The ways in which children delay gratification manifests in heterogeneous manners (Murray et al., 2016; Neuenschwander & Blair, 2017; Wilson et al., 2009) that will be further discussed in Chapter 4. Children’s decision-making about whether to wait or not may also be due to beliefs on reliability of gaining reward (i.e. whether they believe the reward would actually be given), reinforced by experiential and environmental factors (Kidd et al., 2013).

Recent research suggests that behaviorally observable differences in how children delay gratification may correlate to physiological profiles as well (Neuenschwander & Blair, 2017). Theoretical knowledge and empirical evaluations conducted in early childhood have suggested multiple underlying processes involved in regulating anticipatory and impulsive behaviors (Corriveau et al., 2016; Duckworth & Steinberg, 2015; Haimovitz et al., 2020; Mischel et al., 1972; Neuenschwander & Blair, 2017; Pecora et al., 2014). Therefore, a key contribution of this dissertation is to examines such processes and elucidate the multifaceted constructs of voluntary inhibition and associated regulatory components in children.

While the delay task is a laboratory assessment of inhibitory control and regulation, the SDQ is a questionnaire-based measure focused on emotional and behavioral regulation. The SDQ allows for comparing regulatory constructs as reported by parents, teachers and children themselves, using parallel forms of measurement (Goodman, 1997). Using a multi-informant approach to measure behavior and emotional regulation is advantageous because it provides crucial information from several perspectives including mothers, fathers, teachers, peers and children themselves. A review of the current literature on multi-informant reports is presented in Chapter 6. Most commonly, descriptions of children's socioemotional competence are generated through proxy reports, such as parents. However, reliance on proxy reports only may miss important information on children's internal states that they may not outwardly express to their parents/caregivers (Riley, 2004; Vierhaus et al., 2018). Self-reports of emotional and behavioral regulation are most commonly used in adolescence and late childhood; yet, research indicates that children can reliably report on their behavior and feels as early as age 5 (Jardine et al., 2014; Riley, 2004). Limited work has been done to examine the utility of child self-report in middle childhood (ages 8-12 years). Middle childhood is a transition period that is influenced by multiple factors such as family environment, changes in social pressures and increasing encounters with new challenges, especially in middle school (Dubois-Comtois et al., 2013; Essex et al., 2006; Laurens et al., 2017). Precursors of mental health problems often start to emerge in middle childhood as well, but are typically only caught later in adolescence once symptomology has progressed (Ghandour et al., 2019; Ozonoff, 2015). This underscores the necessity for early measurement and detection of behavioral and emotional difficulties and capturing children's self-perceptions, starting as early as the middle childhood period.

This dissertation intends to leverage and integrate multiple assessment methods (observed inhibitory control strategies and multi-informant questionnaire-based data on emotional and behavioral regulation) to capture patterns of development in early and middle childhood.

Early Life Environment and Self-Regulation

Psychological distress has been examined as a mediating mechanism by which external factors such as early life adversity, socioeconomic status and caregiving quality relate to poor physical and mental health (Blair, 2010; Blair & Raver, 2012; Lupien et al., 2018). Stress can be categorized as acute (age-specific, related to tasks), and chronic. Chronic stress has been conceptualized as extreme, frequent or extended activation of the physiological and behavioral stress response system without the buffering of a supportive adult of caregiver (Blair & Raver, 2012; Johnson et al., 2013; Lupien et al., 2018). Chronic stressors include childhood neglect, abuse, poverty, family violence, substance abuse, and parental mental health including, psychological distress problems, collectively referred to as early life adversity (Blair & Raver, 2012; Johnson et al., 2013; Lupien et al., 2018). Adverse early life experiences have been consistently linked to increased risk for emotional and behavioral problems in children, adolescents, and adults (Kushner et al., 2016).

A body of literature has focused on self-regulatory processes as pathways through which external stressors are linked to unhealthy development (Blair, 2010; Blair & Raver, 2012). Animal models have demonstrated the effects of both chronic and acute stress on calibration of behavioral reactivity and poor physiological by altering connectivity and neural functioning within and between the amygdala, hippocampus, and areas of the prefrontal cortex (Blair, 2010; Blair & Raver, 2012; Lupien et al., 2018). These brain regions are responsible for detecting, responding and managing emotional arousal, cognitive processes, and are important for coordinating thought and action for executive functioning (Lupien et al., 2018). In humans, alterations to stress response systems, resulting from early life adversity have been suggested to affect brain development and in turn impede the development of essential goal-directed self-regulatory processes (Blair, 2010; Blair & Raver, 2012; Lupien et al., 2018). Since self-regulatory mechanisms, especially early in development, are caregiver and family-dependent, understanding the dynamic interplay among chronic stress, caregiver aptitude and competing risks is essential.

Although development of internal regulation of emotions and behaviors via inhibitory control is considered a foundational aspect of child development, self-regulatory development in high risk populations is not well understood (Skowron et al., 2014). The importance of caregiver relationships and distress, positive family and social structures with respect to development of self-regulatory capacities involved in inhibitory control and socioemotional competence portray the importance of assessing family, individual and biological aspects of child development. Examining biobehavioral interactions for children who grow up in high-risk environments may provide insight into context-dependent compensatory behavioral and physiological strategies that promote resiliency or vulnerability. It is therefore important to consider contextual factors relating to activation, or over-activation, of emotional and self-regulatory systems, including physiological reactivity, and subsequent implications for health and development.

Psychophysiology and Child Development

Overview of Autonomic Nervous System

The nervous system is a highly complex network that coordinates actions and sensory information through transmitting signals to various parts of the body. The nervous system is divided into the central nervous system (brain, brainstem and spinal cord) and the peripheral nervous system (afferent and efferent nerves). The peripheral nervous system is divided into three subsystems, the somatic, autonomic and enteric nervous systems that coordinate voluntary movement, energy mobilization/homeostatic balance, and control the gastrointestinal system respectively (Kenney & Ganta, 2014). The autonomic nervous system (ANS) is further subdivided into parasympathetic and sympathetic components that will be discussed in more detail below. It is important to note that the autonomic and enteric nervous systems both operate involuntarily, or automatically. The focus here is on the ANS.

The ANS maintains physiological functions involving cardiovascular, respiratory and gastrointestinal systems (Cicchetti & Dawson, 2002; Fox et al., 2006; Mulkey & du Plessis, 2019). Essentially, the ANS works to maintain a state of physiological homeostasis through two branches, parasympathetic and sympathetic. The ANS is also connected to higher brain systems involved in emotional and psychological aspects of life, serving as the impetus for inclusion in this dissertation. The ANS is functionally connected to the brain's limbic structures (e.g. amygdala, thalamus, hippocampus, and hypothalamus), which are involved in mood, memories, and emotional/self-regulation (Mulkey & du Plessis, 2019). The complex interplay between the ANS, brain stem and limbic systems facilitates the basis for the way physical, environmental and social experiences shape behavior, emotion and socioemotional well-being from the prenatal period to adulthood. These interactions are beyond the scope of this dissertation (for review of anatomy of ANS and limbic system connections see (Mulkey & du Plessis, 2019)). Through these processes, the ANS plays a central role in mitigating somatic responses to perceived environmental challenges. Here, we focus on the functions of the sympathetic and parasympathetic branches of the ANS and their implications for developmental research.

The sympathetic branch of the ANS is commonly known to promote the body's "fight or flight" response to adapt to elevated stress and sense of danger. Activation of the sympathetic branch results in increased heart rate, blood flow/circulation to muscles, and activation of sweat glands (Fox et al., 2006). Thus, activation of the sympathetic branch is considered an energy expending response. On the other hand, the parasympathetic branch of the ANS is responsible for the body's "rest and digest" state through increasing gastric and intestinal motility, secretion of digestive juices, increasing salivation and directing blood flow to the gastrointestinal system (Fox et al., 2006; Hinnant & El-Sheikh, 2009). This branch is an autopilot system that drives most daily activity and homeostasis through the vagus, the cranial nerve that regulates deceleratory parasympathetic activity thereby, mediating physiologic reactivity (Grossman & Taylor, 2007; Hinnant & El-Sheikh, 2009; Porges, 2009). The parasympathetic and sympathetic branches work to reciprocally regulate each other in the presence of a stressor. For example, input/processing of stressors within the limbic components of ANS signals increase in sympathetic activation (increase in heart rate, blood pressure, and muscle responsiveness) and ideally the parasympathetic branch would decrease physiologic responses by applying the "vagal break" to down-regulate from the stressor (Porges, 2009), which will be discussed in more detail later. Many functions of the sympathetic and parasympathetic branches oppose each other but continuously and dynamically interact to maintain allostasis (Fox et al., 2006), or the body's adaptation to changing environmental stimuli and the attempt to returning to the pre-stressor physiological state.

ANS within a Developmental Framework

Just like many functions of the nervous system, the ANS matures throughout the fetal period into infancy, first with the development of the sympathetic nervous system during gestation (DiPietro et al., 2015; Mulkey & du Plessis, 2019). The developmental basis for inter-individual differences in ANS function can be seen in the fetal, neonatal, and infant regulation (Mulkey & du Plessis, 2019). Early disruption can influence developmental trajectory of ANS system, including limiting its capacity to respond to physiologic and environmental changes and has been implicated to later neuropsychiatric disorders (see (Mulkey & du Plessis, 2019) for review). Atypical ANS maturation has been linked to various maladaptive outcomes such as hyperactivity, aggressiveness, ADHD in childhood and increased risk of depression and mood disorders into adulthood (Cicchetti & Dawson, 2002; Hinnant & El-Sheikh, 2009; Mulkey & du Plessis, 2019; van der Molen, 2000). The ANS undergoes a long period of development through childhood, remaining vulnerable to disruptions from a variety of influences. Though the focus of this dissertation is not on the multilevel and life course influencers of ANS development, it is important to note and take into consideration when examining the role of ANS in developmental science.

Psychophysiological Evaluation of ANS

Research on physiological correlates and predictors of behavior and development starts as early as the fetal period (DiPietro et al., 2015). Autonomic function can be measured non-invasively from various physiologic signals such as heart rate, respiratory rate, and blood pressure. Variability in these indicators reflect the combination of sympathetic and parasympathetic inputs and is often used to examine ANS maturation (Mulkey & du Plessis, 2019). Psychophysiology is defined as the measurement of reactions/reactivity of physiological systems to changes in psychological state (Fox et al., 2006). This is indicative of how behavioral, psychological and physiological mechanisms work together and reorganize to optimally adapt to the demands of the environment; this is fundamental for initiating, presenting/expressing and terminating behaviors and emotions. Psychophysiological methods have been used extensively in developmental science to examine basic cognitive processes, measure variations in physiological arousal and reactivity, and examine processes underlying emotion and self-regulation (Cicchetti & Dawson, 2002; Fox et al., 2006; Porges et al., 2007; Utendale et al., 2014; van der Molen, 2000).

Psychophysiology provides a means for understanding components of regulation that are not be accessible through observational or questionnaire-based methods alone. Examining the actions of targeted physiological systems as they change in response to psychological challenges or stressors allows developmental researchers to construct multidimensional psychophysiological profiles (Fox et al., 2006). In addition, trajectories of development are often based in interactions between nervous system readiness to react and adaptations of physiologic systems over time (Fox et al., 2006). Therefore, finding psychophysiological links and patterns of typical and atypical development is critical to understanding the junction between observable and unobservable components of child development and well-being.

Early psychophysiological work was rooted in infant heart rate and changes in heart rate (Cicchetti & Dawson, 2002; Fox et al., 2006). It was quickly noted, however, that the impetus for such changes in heart rate was not clear or independent from influences such as motor activity and metabolic changes. Therefore, a multi-determinant approach was formulated to enhance the precision of physiological links to specific psychological processes, allowing for more cohesive models that assess how the body facilitates the adaption and response to environmental stressors and psychological challenges (Cicchetti & Dawson, 2002; Fox et al., 2006). This approach included the evaluation of multiple indicators of physiologic function indicated by parasympathetic and sympathetic indicators and the timing of physiological events underlying behavioral responses to stressors (Cicchetti & Dawson, 2002; Fox et al., 2006). There are many methods to evaluate the psychophysiological link, here we focus on physiological arousal/reactivity in the ANS.

Sympathetic and Parasympathetic Autonomic Indicators

One of the most salient and easily observable indicators of autonomic activation is heart rate, specifically patterns of heart rate and variability typically characterized through inter-beat intervals (IBI), standard deviation of heart rate, standard deviation of R-R or N-N (standardized) peaks, or root mean square of successive differences in R-R or N-N peaks (Cicchetti & Dawson, 2002; Fox et al., 2006; Valenza et al., 2018). In a pioneering paper, Fowles (1980) points to empirical evidence linking patterns of heart rate with the behavioral activation system (BAS), when somatic activity, such as motor activity, is controlled for (Fowles, 1980).   BAS reflects the internal control system that responds to incentives and reflects internal motivation (Blair, 2003). This system is important when studying anticipation and motivation underlying self-regulation components, specifically inhibitory control. Numerous studies since Fowles' work have examined patterns of heart rate with respect to self-regulation and socioemotional development (e.g.(Blair, 2003; Holzman & Bridgett, 2017; Mezzacappa et al., 1998; Ramirez et al., 2015; Wilson et al., 2009).

Variation in heart rate over time is often used in conjunction with respiratory rate to quantify rhythmic cardio-respiratory oscillations, known as respiratory sinus arrhythmia (RSA), as a proxy measure of vagal tone (Holzman & Bridgett, 2017). Vagal influence during exhalation slows heart rate while vagal influence during inhalation increases heart rate creating a measure for variance in cardiac inter-beat intervals driven by respiratory regulation (Fox et al., 2006). The vagal system conveys information regarding visceral state to the central nervous system where it is interpreted and acted upon, resulting in changes to regulation of heart rate via vagal efferent pathways, measured through RSA (Porges et al., 2007). Individual differences in RSA at rest and changes in RSA levels in response to stressors or challenges are both a part of parasympathetic functioning, mediated by cardiac vagal tone (Porges et al., 2007). Of note, Porges' polyvagal theory proposes that baseline RSA reflects the individual's readiness to engage with the environment and change or regulation of RSA in response to a stressor reflects the individual's ability to engage or disengage with the challenges, thus, offering a link between parasympathetic regulation and emotional regulation.

Cardiac vagal tone, controlled by the vagus nerve, acts as a "brake" that slows heart rate in the absence of threats or challenges (Hinnant & El-Sheikh, 2009); in the presence of a stressful stimuli, the vagal "brake" is lifted and facilitates sympathetic responses such as increases in heart rate. Efficient suppression of this vagal brake is necessary when activity or attention is required for coping with environmental demands and often measured through basal levels of RSA and changes in RSA (Hinnant & El-Sheikh, 2009). A combination of high basal vagal tone and appropriate vagal suppression in response to a challenge/stressor is considered to create the optimal physiologic state to engage in self-regulation, attentional focus, and problem solving (Coulombe et al., 2019; Hinnant & El-Sheikh, 2009). Quantifying the magnitude of an individual's RSA is necessarily not a direct measure of neural activity but is a widely accepted proxy indicator of parasympathetic reactivity and flexibility in the literature (Fox et al., 2006; Mulkey & du Plessis, 2019; Porges, 2009; Sturge-Apple et al., 2016). ANS indicators and their role in self-regulation and inhibitory control specifically will be discussed in Chapter 5.

Psychophysiology provides tools to examine physiological change, concurrent with behavior change, in response to a psychological perturbation or stressor. Individual differences in children's psychophysiological responses to stress play a key role in understanding typical and atypical development and developmental psychopathology (Cicchetti & Dawson, 2002; Hinnant & El-Sheikh, 2009). Disassociations between overt behavior and underlying expected physiology reactivity may implicate a disruption in self-regulatory capacity. One of the studies in this dissertation evaluates the underlying physiologic processes, including the confluence of parasympathetic and sympathetic activation, with respect to inhibitory control and behaviorally observable regulation strategies.

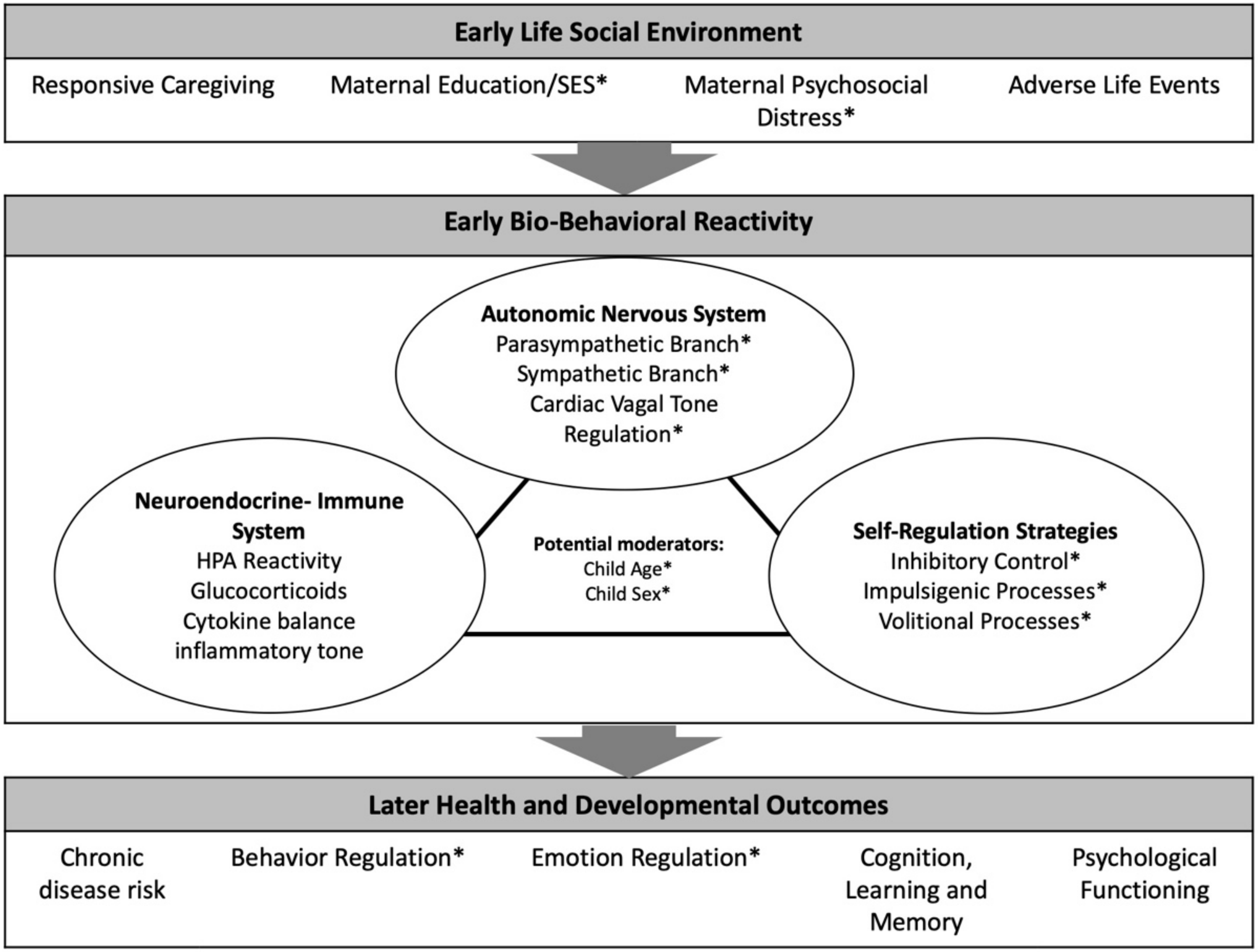
2.2 Conceptual Framework

The conceptual framework presented here (Figure 2.1) is derived from the current knowledge base and theories surrounding biobehavioral development. This framework is adapted and modified from Johnson et. al. 2013 with support from empirical and theoretical concepts reviewed thus far. The goal is to summarize how early family and social factors are translated into health and developmental outcomes through biological, with a specific focus on autonomic regulation, and behavioral derivatives. Developmental trajectories vary considerably among children exposed to different environmental factors, therefore understanding multi-level moderators of regulation at each stage of development is imperative (Johnson et al., 2013). A dynamic developmental systems approach allows for the examination of how behavior is shaped by constant feedback across bioecological systems encompassing individual, family, and social influences, as well as bidirectional associations between behavior and biology (Muller et al., 2013; Tiberio et al., 2016). Studies surrounding child behavioral and physical developmental milestones have been traditionally grounded in a developmental systems approach to gain a multi-level life course perspective (i.e. (Golenia et al., 2018; Marshall, 2013; Reynolds & Roth, 2018; Tiberio et al., 2016)).

Developmental systems theory (DST) is a reworking of biological and environmental concepts, focusing in on the interactionist approach to the nature/nurture debate: the real debate is not in nature *versus* nurture, but rather how much and when nature *and* nurture contribute to developmental trajectories (Oyama et al., 2001). DST provides a framework for empirically understanding the reciprocal role of biology, individual traits, family dynamics and larger social contexts on human development. As illustrated in Figure 2.1, it draws on both intrinsic factors (i.e. behavior, biology/physiology) and extrinsic factors (i.e. family, maternal distress, SES) to emphasize the combined and distributed processes over time involved in human development and well-being. DST is not attributable to one person or group, but rather draws insights from a myriad of researchers and fields including genetics, neuroscience, psychology and sociology (Oyama et al., 2001).

Joint determination by multiple causes, one of the themes of DST, captures the concept that there are many influences on development which interact and differentially hold importance over the course of development (Oyama et al., 2001). This theme will be important for conceptualizing the differential role of early self-regulatory strategies, manifested as inhibitory control, and early physiological regulation on later development of emotional regulation, all nested within the larger family and social level systems. Therefore, guided by the developmental systems approach and existing framework for the role of biological and early life experiences on health and developmental outcomes (Johnson et al., 2013), this dissertation examines family (maternal distress and social risk factors), individual (behavior/emotional regulation), and biological (autonomic regulation) influences on child socioemotional development. Concepts most important to this dissertation are denoted by asterisk in Figure 2.1.

Figure 2.1. Adaptation of Johnson et al.'s framework for studying early individual, family and social factors related to health and development[a]



a: Adapted and modified from Johnson et al. 2013

* Denotes variables of interest for dissertation

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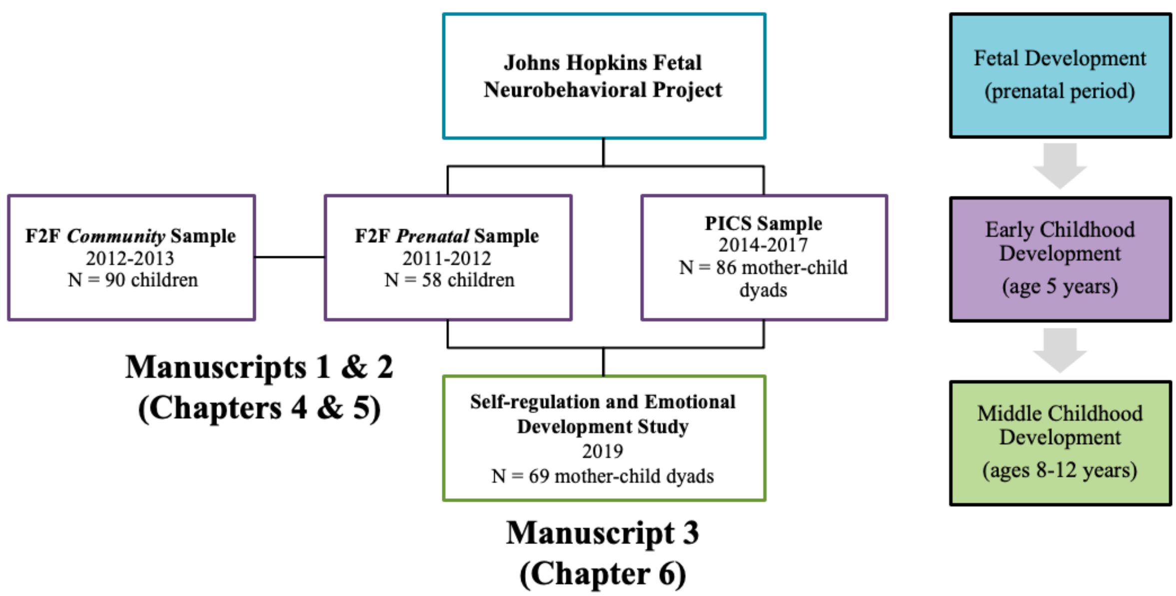
CHAPTER THREE

Study Design and Methods

3.1 Study Design Overview

This dissertation relies on two distinct sources of data. The first source involves existing data generated by a study focused on the development of cognitive processing, executive function, and self-regulatory behaviors in a sample of 5-year-old children. The second source of data was generated as primary data for this dissertation and is focused on maternal, teacher and child self-reports of behavioral and emotional difficulties in children aged 8-12. The schematic below shows existing sources of data, new primary data collected, and the manuscripts generated from each; details related to each will be described in turn. Eligible sample sizes of mother-child dyads are presented in this schematic and further detailed below.



This chapter presents study procedures, sample characteristics, methods and analytics will be described for existing data (Manuscripts 1 and 2 comprising Chapters 4 and 5) first, followed by the same information for the primary data collected (Manuscript 3, Chapter 6).

3.2 Existing Data: Fetus to Five

Participants

Fetus to Five (F2F. S. Johnson) is the title of the study examining cognitive processing, executive functions and self-regulation in 5-year old children. It includes a sample of families who originally were recruited as a prenatal cohort within the Johns Hopkins Fetal Neurobehavioral Project (J. DiPietro) referred to as the *prenatal* sample and an additional sample of mothers and their 5- year old children drawn from that same local area but drawn specifically from residents of a large urban center (referred to as the *community* sample*)* (Riis et al., 2015).

The *prenatal* sample was recruited between 2006 and 2007 (Cohort VI of the Fetal Neurobehavioral Project) and followed up for F2F between 2011 and 2012. Initial enrollment was limited to low-risk, non-smoking women with healthy, singleton pregnancies (see (DiPietro et al., 2010) for further details). F2F data were collected from 57% of eligible maternal-fetus pairs (*n* =128) from the *prenatal* sample, resulting in laboratory-visit data for 58 mother-child pairs and 15 mothers who participated remotely via mail surveys.

In order to broaden sociodemographic characteristics, mother-child pairs were recruited from Baltimore City through community postings and fliers around the city (i.e. community centers, churches, markets). To be eligible for participation, mothers had to be either the biological mother or legal guardian of the child, and fluent in English. The *community* sample included laboratory data collected from 90 mother-child pairs.

Children in both samples were excluded if their mothers reported significant health conditions or developmental disabilities that impair cognitive, motor, or regulatory functioning. 151 mother-child dyads participated in laboratory visits. Children from F2F *prenatal* and *community* samples were comparable on age at time of study visit, however, as anticipated, other maternal and child demographic information varied greatly.

Sample Characteristics

On average, mothers in the *prenatal* sample were well-educated (*M* = 17.9 years education, *SD* = 2.9), with 54% having a master's degree or higher, mature (*M* = 37.4 years of age, *SD* = 4.5), married (94.4%), and predominantly non-Hispanic white (77%) with the remainder distributed as 4% white Hispanic, 13%, African American, and 6% Asian. Children were also predominantly non-Hispanic white (72%) with similar race distribution as mothers. Fifty-five percent of the children were female. At the time of data collection, children were 5.3 years old (*SD* = .29) with 68% of children in pre-kindergarten or kindergarten.

Mothers in the *community* sample on average completed high school, (*M* = 12.5 years education, *SD* = 2.1), with 10% having a four-year college degree or higher, 29.9 years of age, (*SD* = 6.5 years), currently unmarried (80%), and predominantly African American (88%) with the remainder of mothers distributed as non-Hispanic white (9%) and other (3%). Children were also predominantly African American (91%) with similar race and ethnicity distribution as mothers. Forty-nine percent of the children were female. At the time of data collection, children were 5.5 years of age (*SD* = .28) with 75% of children in pre-kindergarten or kindergarten.

Of the 151 children who came in for laboratory visits, 54 from the prenatal sample and 90 from the community sample had a recorded and useable delay of gratification task (*n* = 3 had incomplete visits/did not complete delay of gratification task (all in *community* sample*), n* = 4 with no video data (all in *prenatal* sample)), thus, resulting in a sample of 144 children. It is important to note that 11 children (n = 9 boys) ate the snack reward right away and therefore do not have any coded inhibitory control data. Analytic samples for Manuscript 1 and Manuscript 2 slightly differ, but sample composition is comparable.

Procedures and Measures

Study visits for F2F were conducted in a dedicated space in Hampton House of the Johns Hopkins Bloomberg School of Public Health. Visits lasted approximately 90 minutes during which children engaged in a battery of tasks to assess cognitive and executive functioning and emotional regulation. Electrocardiograph (ECG) data were collected throughout study visits on children, producing measure of heart rate and respiratory sinus arrhythmia (RSA). All lab tasks were audio/video recorded. At the same time, mothers completed questionnaires on themselves and their child's behavior and development in a separate room.

Delay of Gratification Task

The study protocol employed the standard Delay of Gratification task (referred to as delay task in this dissertation) as developed by Mischel and colleagues (Mischel et al., 1989). This delay task is developmentally appropriate to assess inhibitory control and has been shown to challenge behavioral and emotional regulation in young children (Mischel et al., 1989). Children are seated with a bell in front of them and asked to select a snack of their choice (marshmallow or pretzel). ***Instruction period:*** The child is told that the research assistant (RA) will leave the room for some time and not to eat the snack until the RA returns. The child is also instructed that ringing the bell brings the RA back into the room and allows for him/her to eat the one snack in front of them right away; however, if he/she waits for the RA to return (without child ringing bell), he/she will be rewarded with two snacks. ***Task period:*** The child is left alone for eight minutes or until he/she rang the bell to bring the RA back. Delay ability (waited vs. did not wait for the full 8 minutes) had been previously coded for this task.

For the purposes of this dissertation, videos underwent additional coding of motor, vocal and anticipatory self-regulatory strategies were introduced to assess individual differences that contributed to ease or difficulty in delaying the full task time. Interval coding (i.e., every 30 seconds) of audio/video was used to code the presence and degree of motor behaviors and vocal self-regulation, while a global anticipation score was assigned after viewing videos. ***Motor Activity***. Degree of motor behaviors was coded on a scale of 1 to 3 as no/low motor activity (sitting still, discrete movements), moderate motor activity (fidgeting constantly, moving head/arms/legs), and high motor activity (kicking legs, clapping hands, up and down in chair). One motor behavior category was coded for each interval. ***Vocalizations.*** Degree of vocal self-regulation was coded on a scale of 1 to 3 as no/low (no audible mouth movements or vocalizations), moderate vocalization (quiet self-talk, sighing), and high vocalization (singing, yelling). Again, only one vocalization category was coded for each interval. ***Anticipation***. A global anticipatory self-regulation score was assigned for each child after reviewing the task.

These coding schemes are based on previous behavioral rating systems for inhibitory control tasks (Goldsmith & Rothbart, 1999) and observations of child behavior from task videos. Coding schemes for motor, vocal and anticipatory behaviors are in the Appendix A. Tasks that ran longer than 480 seconds due to errors in protocol were truncated at 480 seconds (i.e. if the child waited the 480 seconds, they were considered to have delayed the whole time). Twenty percent of videos were double coded by a trained RA to establish reliability in self-regulation coding. Inter-rater reliability was examined using weighted Cohen's kappa to account for degree of differences. Kappa values greater than .70, considered as substantial inter-rater agreement, were the cutoff point for each coded variable. Any differences in behavior coding between the two coders was resolved through discussion.

Psychophysiological Data

Participating children were seated in a chair during the study visit and heart rate acquisition. After cleansing skin with alcohol pads, three Bio-Detek (Pawtucket, RI) LT303P White Cloth Wet Gel Pediatric 1 ½” Round Electrodes were placed on each child. The first electrode was placed on the right clavicle near the sternum, superior to the first rib. The second electrode was placed near the junction of the transpyloric and midclavicular planes. The final electrode was placed on the upper abdomen near the lower right rib. ECG data were sampled at 1000 Hz and recorded continuously for the duration of the laboratory visit on Mindware Technologies, LTD (Columbus, OH) BioNex Desktop Platform.

Analyses here are performed on digitally detected R-waves of the ECG using Mindware Technologies, LTD’s Heart Rate Variability (HRV) Analysis Software Version 3.2.3. Intervals between R-waves were timed in msec (i.e., inter-beat-interval (IBI)). Artifact was detected using dual algorithms (IBI Min/Max and MAD/MED) configured within Mindware. The IBI Min/Max algorithm flags values that fall above or below the specified maximum (200 bpm) and minimum (40 bpm) thresholds. The MAD/MED algorithm examines the variability of IBIs and flags outliers as potential artifact (see (Berntson et al., 1990) for further details). R-waves that were identified as potential outliers were marked and subsequently manually edited using standard practices (i.e., deleting erroneous R-waves and adding missing R-waves when skipped). Segments with more than 5% estimated R-waves were dropped. Psychophysiological data were individually extracted and aggregated into an analyzable database as heart rate and respiratory sinus arrhythmia (RSA).

Heart rate (HR) during the instruction period (total) and task period (total and 30 second intervals, up to 16 intervals based on delay time), measured as beats per minute (bpm), was computed for each participant. Since respiration bands were not used during data collection, RSA was calculated within Mindware based on IBI time series and spectral analysis using high frequency heart rate variability as follows: RSA= ln (HFPower). RSA was calculated for the frequency band 0.15-0.8 Hz, as typically done to account for children's faster rates of breathing (Bar-Haim et al., 2000). Mean RSA during the instruction period (total) and task period (total and 30 second intervals, up to 16 intervals based on delay time) was analyzed for each participant.

Maternal and Child Characteristics

Maternal age, education, marital status, race and ethnicity was collected through maternal report. Child age, sex, race, ethnicity and whether or not the child attended pre-K or Kindergarten were also collected through maternal report. Given that the delay task uses a snack as a reward, child body mass index (BMI) was examined as a confounder. Child height and weight measured at the study visit were used to compute age and sex adjusted BMI. Categorical weight status (underweight/healthy or overweight/obese) was assigned for each child based on the Center for Disease Control and Prevention's BMI percentile ranges for children (*Healthy Weight: About Child & Teen BMI.*, 2018).

Child Receptive Language. Children's Peabody Picture Vocabulary Test (PPVT) was administered during the lab visit. The Delay of Gratification task relies on children's abilities to comprehend and follow the rules presented to them. Therefore, to account for children's verbal intelligence we examine PPVT scores (standardized *within* the sample) as a potential confounder.

Maternal Psychological Distress. Women's psychological distress was measured using following: 1) State-Trait Anxiety Inventory (STAI), designed to assess state and trait levels of anxiety (Spielberger, Gorsuch, & Lushene, 1968); 2) Center for Epidemiological Studies-Depression (CES-D), a measure of depressive symptoms (Radloff, 1977); and 3) Parenting Stress Index, Fourth Edition Short Form (PSI-SF), measuring three domains of parenting-related stress including parental distress, parent-child dysfunctional interaction, and difficult child which combine into a Total Stress scale (Abidin, 2012). A maternal distress factor score that had been derived from prior work was used in the analyses (for details on factor analysis see (Riis et al., 2016)). Higher scores for this variable indicated higher levels of maternal distress.

3.3 Manuscript 1 Analytic Sample, Exploratory Analyses, and Hypotheses Testing

Analytic Sample

The analytic sample for Manuscript 1 includes 144 children who participated in the delay task (n = 54 children from the *prenatal* sample and n = 90 children from the *community* sample). Since 11 children ate the snack reward right away, analyses that include inhibitory control data are limited to 133 children. Details of analytic sample derivation and variables used are described in Chapter 4.

Exploratory Data Analysis and Missing Data

Distributions of all means of continuous variables and frequency distribution for categorical variables were examined visually and using the Shapiro-Wilk test for normality. This informed the use and split of variables into dichotomous and categorical as needed/indicated. Multicollinearity between sociodemographic variables and sample indicator were checked using variance inflation factors (VIF) and Pearson correlation coefficients (r). Assessing multicollinearity is important as to not occlude potential associations due to the collinear nature of independent variables of interest.

Audio/video recordings that were unable to be coded (i.e. due to camera angle, video quality, playback errors) were excluded from the final analytic sample. Data were examined for missing values and to establish patterns of random vs. informative missingness. There was no missing data in the inhibitory control behavior variables, as steps were taken to ensure complete behavioral data coding. Five children had no values for delay ability, which was corrected by examining audio/video recordings. Seven children had no BMI data and no height/weight recorded; for analyses that explicitly examined child BMI, sample was restricted to children with complete BMI data only (n = 126).

Hypotheses Testing

The goal of Manuscript 1 was to explore five-year-old children's spontaneous use and intensities of various self-regulatory strategies, such as motor activity and vocalizations, and levels of anticipatory behaviors during the delay task by testing the following hypotheses.

Hypothesis 1.1. Children who show low to moderate levels of motor activity (i.e., in seat, fidgeting), vocalizations (i.e., whispering, self-talk/distraction) and anticipation (i.e., attention away from reward) will be able to delay the full task time as compared to children who show high levels of these components.

- ***Dependent Variables:*** Inhibitory control components (motor activity, vocalizations, and anticipation) were examined separately as outcomes
- ***Independent Variables:*** To assess sociodemographic correlates of motor activity, vocalizations, and anticipation, selected maternal and child characteristics including maternal age, maternal education (in years), child age, child sex (1 = boys, 2 = girls),

child BMI (categorical, 1 = overweight/obese, 0 = normal weight/underweight), and an indicator for sample (1 = *prenatal,* 2 = *community*) were examined as unadjusted and adjusted predictors of child inhibitory control components

Analytic Method: Two sample t-tests, χ^2 analyses, Pearson correlation coefficient and ANOVA/ANCOVA were used to test sociodemographic correlates of inhibitory control components utilized during the delay task. Bivariate and multivariate logistic regression analyses were used to test how each inhibitory control component independently related to delay ability

Example multivariate logistic model for examining how each inhibitory control (IC) component independently predicted delay ability:

$$Log\ Odds(Y_i) = \beta_0 + \beta_{1-3}C_{1-3} + \beta_{4-5}M_{4-5} + \beta_6 S_6 + \beta_7(IC\ Component_7)$$

Where,

Y_i = Delay Ability (0 = did not delay full task time, 1 = delayed full task time)

C_{1-3} = Child characteristics (age, sex, BMI category)

M_{4-5} = Maternal characteristics (age, education)

S = Indicator for sample (*prenatal* vs. *community)*

$IC\ Component$ = either motor activity, vocalizations or anticipation

Multivariate logistic regression models were evaluated for model fit using model fit statistics and diagnostics (i.e., Hosmer-Lemeshow test, Akaike Information Criterion (AIC), Bayesian information Criterion (BIC)).

Hypothesis 1.2. Motor activity, vocalizations, and anticipatory behaviors will cluster in distinct patterns of child inhibitory control capacity.

- ***Measured/Observed Indicators:*** To index inhibitory control, motor activity and vocalizations composite scores were entered as continuous variables, where higher scores indicated higher levels of observable motor activity and audible vocalizations used by children, respectively; anticipation was used as a categorical variable (1= low, 2 = moderate, 3 = high) with dummy indicators for moderate anticipation (1 = yes vs. 0 = no) and high anticipation (1 = yes vs. 0 = no) used to fit the latent class measurement model.

Analytic Method: Latent class analysis was employed for Hypothesis 1.2. One, two and three class models were fit without covariates for the 4 listed indicators. Several indicators of latent class model fit were examined. Information criterion (Bayesian information Criterion (BIC), sample size adjusted-BIC, Akaike Information Criterion (AIC)) were used to determine model fit during class enumeration, with lower values indicating better model fit. In addition, models that differed in the number of classes were examined using Lo-Mendell-Rubin (LMR) and Bootstrap Likelihood Ratio (BLRT) tests, and associated p-values, to see whether adding an additional class significantly improved the model fit. Full Information Maximum Likelihood (FIML) estimation was used to handle missing data. Final latent class model selection was based on lowest AIC, BIC (or largest decrease in information criterion) and significant LMR and BLRT parameters. Class specification was examined via entropy. Entropy ranges between 0 and 1, where a value of 1 indicates perfect classification. In this Manuscript, entropy value > .90 considered as great class specification. Sample size within each class, and interpretability of indicated classes were also examined.

The latent class analysis model used here assumes that any association among the observed variables (motor activity, vocalizations, anticipation) are entirely explained by the latent class variable derived (conditional independence assumption). The joint distribution of indicators and the latent class variable, c, under the conditional independence assumption is expressed below (Nylund-Gibson & Choi, 2018):

$$\Pr(u_{1i}, u_{2i}, u_{3i}, u_{4i}) = \sum_{k=1}^{K}[\pi_k \cdot (\prod_{m=1}^{M} \Pr(u_{mi} | \, c_i = k)]$$

Where,

> *M* = observed latent class indicators, $u_{1i}, u_{2i}, u_{3i}, u_{4i}$, representing motor activity, vocalizations, moderate anticipation and high anticipation respectively. The model assumes that the *M* indicators are all measures of an underlying categorical latent class variable, *c*, having *K* number of classes that are mutually exclusive and exhaustive.
>
> π_k = proportion of individuals in a given latent class, k
>
> $\Pr(u_{mi} | \, c_i = k)$= logit value for class specific indicator probabilities (conditional item probabilities/measurement parameters) that describe the relationship between observed indicators and the latent categorial variable, *c*.

The latent variable diagram for the derived inhibitory control classes is in Chapter 4 (Figure 4.1).

Hypothesis 1.3. Children who use moderate inhibitory control strategies will be able to delay more successfully as compared to children who exhibit low or higher levels of these constructs.

- ***Dependent Variable:*** the outcome variable to test Hypothesis 1.3 is a binary indicator for delay ability (0 = did not delay full task time, 1 = delayed full task time).
- ***Independent Variable:*** derived latent inhibitory control (IC) classes from Hypothesis 1.2.
- ***Key Covariates:*** key covariates were selected based on prior literature on confounders of inhibitory control and child self-regulation development (e.g. (Power et al., 2016; Watts et al., 2018)). These covariates included maternal age, maternal education, maternal distress, child age, child sex, child BMI, child PPVT score, and sample indicator.

Covariates that were not considered theoretical confounders and did not reach p <.10 significance in preliminary analyses were dropped in subsequent analyses.

Analytic Method: to test for maternal and child characteristics that may contribute to differences in child inhibitory control, selected covariates were regressed onto the final class enumeration model using linear and logistic regression models. IC classes based on posterior class probabilities, from the final class enumeration model, were used as predictors of delay ability using bivariate and multivariate logistic regression analyses.

Example multivariate logistic regression model used to test this hypothesis:

$$Log\ Odds(Y_i) = \beta_0 + \ \beta_{1-3}C_{1-3} + \beta_{4-5}M_{4-5} + \beta_6 S_6 + \beta_7(IC\ classes_7)$$

Where,

Y_i = Delay Ability (0 = did not delay full task time, 1 = delayed full task time)

C_{1-3} = Child characteristics (age, sex, BMI category)

M_{4-5} = Maternal characteristics (age, education)

S = Indicator for sample (*prenatal* vs. *community)*

$IC\ classes$ = categorical indicator for derived latent classes

Again, multivariate logistic regression models were evaluated for model fit using criteria and diagnostics (i.e., Hosmer-Lemeshow test, Akaike Information Criterion (AIC), Bayesian information Criterion (BIC)).

3.4 Manuscript 2 Analytic Sample, Exploratory Analyses, and Hypotheses Testing

Analytic Sample

The analytic sample for Manuscript 2 includes 126 children (n = 50 children from the *prenatal* sample and n = 76 children from the *community* sample), who participated in the delay task, had inhibitory control data, and usable psychophysiological data. Details of analytic sample derivation and variables used are described in Chapter 5.

Exploratory Analyses and Missing Data

Distributions of all means of continuous variables and frequency distribution for categorical variables were examined visually, using histograms and boxplots, and empirically using the Shapiro-Wilk test for normality. This informed the use and split of variables into dichotomous and categorical as needed/indicated. Multicollinearity between sociodemographic variables and sample indicator were checked using variance inflation factors (VIF) and Pearson correlation coefficient (*r*). Psychophysiological data from 25 kids required edits to reduce artifact in R-waves. The editing process for psychophysiological data is described in Chapter 5.

Distributions of mean heart rate (HR) and mean respiratory sinus arrhythmia (RSA) during the instruction and task periods were examined for outliers using histograms. For HR, values that were above 3 standard deviations to the mean were interpolated using the "nearest neighbor" method (Morelli et al., 2019). Two children had outliers when examining mean HR during the task and required interpolation; sensitivity analyses comparing overall mean HR with interpolated values and treating outliers as missing revealed no differences, therefore interpolated values were retained. Two children were missing values for mean RSA during the instruction period; these children were different than the ones with outlier values for HR, therefore, analyses including instruction RSA are limited to n = 124 children.

Distributions overall task RSA revealed three outliers. ECG data for these three cases were re-examined within Mindware Technologies, LTD Heart Rate Variability (HRV) Analysis Software Version 3.2.3 and R-waves were corrected for the segments with task RSA outliers, before re-exporting the data. Again, sensitivity analyses were conducted to examine differences between corrected task RSA values and treating missing cases as missing, revealing no differences. To maximize sample size, corrected task RSA values were used, therefore task RSA sample remained n = 126. Missing data and exploratory analyses for behavioral and covariate data were described in Section 3.3 (Manuscript 1).

Hypotheses Testing

Manuscript 2 sought to assess physiological regulation underlying children's inhibitory control by quantifying heart rate and respiratory sinus arrhythmia (RSA) during the instruction and task periods of the delay task in 5-year-old children. The following hypotheses were evaluated.

Hypothesis 2.1: Children who delay the full task time will have differentiating levels and patterns of heart rate and RSA as compared to children who do not delay the full delay of gratification task time.

- ***Dependent Variable:*** The dependent variable for Hypothesis 2.1 is a binary variable for delay ability (0 = did not delay full task time, 1 = delayed full task time).
- ***Independent Variables:*** Mean instruction HR and RSA, mean task HR and RSA, and two sets of change scores (dMeanHR, dMeahRSA: mean values during task period – instruction period, for HR and RSA separately; and dDelayHR, dDelayRSA: mean values end of task – mean values start of task, for HR and RSA, separately) were examined as predictors of delay ability. Additionally, mean epoch by epoch HR and RSA values were derived from 30-second interval data and used to look at differences in delay ability.
- ***Sociodemographic Correlates:*** selected maternal, child and sample characteristics were assessed with independent and dependent variable to identify potential confounders.

Analytic Method: Exploratory and bivariate analyses (i.e., histograms, box-plots, t-tests, χ^2 tests and Pearson correlation coefficients) were used to examine distribution of HR and RSA measures and sociodemographic correlates. Bivariate analyses (two sample t-tests, Mann-Whitney two-sample tests) were used to test associations between physiological variables and delay ability. Plots of mean HR and RSA during the delay task were generated to examine values in 30 second epochs. Differences in HR and RSA patterns between children who delayed and did not delay were examined using two sample t-tests, Mann-Whitney two-sample tests, and variance ratio tests. Mixed effects models, with and without a time by delay interaction term, were considered to further quantify patterns in HR and RSA. This was solely exploratory due to small sample sizes for the group of children who did not delay. Bivariate analyses and examination of epoch by epoch mean plots will be used to inform which independent variable(s) best characterized physiological reactivity for the delay task.

Hypothesis 2.2: Children with lower pre-task heart rate/higher RSA will be able to delay more successfully than children who have higher pre-task heart rate/lower RSA. Children with less increase in heart rate/decrease in RSA to task will be able to delay more successfully than children whose heart rate and RSA substantially increase to task.

- ***Dependent Variable:*** Binary variable for delay ability (0 = did not delay full task time, 1 = delayed full task time) was the outcome.
- ***Independent Variables:*** Two sets of change scores (dMeanHR and dMeanRSA: mean values during task period – instruction period, for HR and RSA separately; and dDelayHR dDelayRSA: mean values end of task – mean values start of task, for HR and RSA during task, separately) were used as predictors of delay ability.

- ***Key Covariates:*** Covariates that were retained for these analyses were maternal age, maternal education, child age, child sex, child BMI category, sample (*prenatal* vs. *community)*, and instruction duration. These covariates were selected based on results from testing Hypothesis 2.1.

Analytic Method: Multivariate logistic regression models with key covariates added in a stepwise manner were used to examine relationships between selected physiological measures and delay ability. Models were evaluated for fit using model fit statistics and diagnostics (i.e., Hosmer-Lemeshow test, Akaike Information Criterion (AIC), Bayesian information Criterion (BIC)).

Hypothesis 2.3: Heart rate and RSA will moderate the relationship between inhibitory control classes and delay ability such that children whose inhibitory control strategies helped them delay will have less heart rate and RSA change as compared to children who had ineffective inhibitory control strategies.

- ***Dependent Variable:*** Delay ability (0 = did not delay full task time, 1 = delayed full task time) was the outcome.
- ***Independent Variable:*** derived latent inhibitory control (IC) classes from Manuscript 1 was the predictor variable
- ***Moderator:*** HR and RSA variables that significantly relate to delay ability will be examined. These variables will be selected based on testing Hypotheses 2.1 and 2.2.
- ***Key Covariates:*** Covariates that were retained for this moderation analysis were maternal age, maternal education, child age, child sex, child BMI category, sample (*prenatal* vs. *community)*, and instruction duration.

Analytic Method: A three-step approach to mixture modeling was used to examine the moderating role of HR and RSA variables. First, a latent variable model using indicators for motor activity, vocalizations and anticipation was run and a three-class model was selected (see Chapter 4 (Manuscript 1) for details). Second, an unconditional model was run to create BCH weights (reflects measurement error of latent class variable and prevents class shifting in subsequent analyses). Third, using BCH weights, the moderating role of selected HR and RSA variables on the relationship between IC classes (independent variable) and delay ability (dependent variable) was tested using an interaction term: IC class by HR and RSA variables. Three separate moderation models were run 1) with HR variable(s), 2) with RSA variable(s), 3) with both HR and RSA variables together.

Example multivariate logistic regression model used to test this hypothesis:

$$Log\ Odds(Y_i) = \beta_0 + \ \beta_{1-3}C_{1-3} + \beta_{4-5}M_{4-5} + \beta_6 S_6 + \ \beta_7 ID_{7+} \beta_8(IC\ class_8) + \beta_9(Physio)_9 + \ \beta_{10}(Physio\ x\ IC\ Class)_{10}$$

Where,

Y_i = Delay Ability (0 = did not delay full task time, 1 = delayed full task time)

C_{1-3} = Child characteristics (age, sex, BMI category)

M_{4-5} = Maternal characteristics (age, education)

S = Indicator for sample (*prenatal* vs. *community)*

ID = instruction duration (continuous, seconds)

$IC\ class$ = categorical indicator for derived latent classes

$Physio$ = physiological measures (based on testing Hypotheses 2.1 and 2.2)

$Physio\ x\ IC\ Class$ = interaction term for physio by IC class moderation analysis

3.5 Statistical Software for Manuscripts 1 and 2

Analyses for Manuscript 1 (Chapter 4) and 2 (Chapter 5) were conducted using Stata version 16.1 (StataCorp, 2019) and *Mplus* version 8 (Muthén & Muthén, 1998-2017).

3.6 New data collection: Self-Regulation and Emotional Development Study

The Self-regulation and Emotional Development Study (SEDS; R. Raghunathan) encompassed a single questionnaire-based follow up of children aged 8-12 years, extending two prior longitudinal fetal cohort studies (F2F *prenatal*; S. Johnson and Prenatal Indicators of Self-Regulation, PICS; K. Voegtline) into later childhood. The goal of SEDS was to compare and contrast maternal, child and teacher reports of socioemotional development in middle childhood and examine the role of maternal and child factors on multi-informant concordance and discordance. Mother-child pairs who participated in F2F *prenatal* or PICS study visits, and who had children between the ages of 8-12 years at time of data collection, were contacted for follow-up.

Participants

Families who had completed F2F (*prenatal* sample) and PICS study visits when their children were 5 years of age were eligible for follow-up (n = 146 mother-child dyads). Of the 146 families, 134 mother-child pairs were considered for participation based on child's age eligibility (child age from 8 to 12 years) at time of data collection; two additional children were excluded due to previously diagnosed developmental conditions. Fourteen sibling pairs were in the original pooled sample, however, only one sibling (typically the older and/or age eligible child) was included in this study. This resulted in a sample of 118 mother-child pairs who were attempted to be contacted.

About 25% (n = 28) of families had outdated contact information (i.e. email bounced back, phone number no longer in service, no alternate contact was found). Of the remaining 90 families, 69 mother-child pairs responded and agreed to participate, one family declined, and 21 families did not respond. Sixty-seven mothers, 64 children and 47 teachers ultimately participated. There were no differences in maternal age, maternal education, maternal race, maternal marital status and child sex between responders and non-responders, therefore analyses were restricted to responders only with no further analytic techniques (i.e. inverse probability weighting, propensity scores) employed.

Sample Characteristics

Women in this sample were well-educated (M = 17.6 years education, SD = 2.1), mature (M = 43.2 years of age, SD = 4.8), married (90%), and predominantly non-Hispanic white (76%) with the remaining mothers as 9% white Hispanic, 6% African American; 7% Asian, and 1% multi-racial. Children were also predominantly non-Hispanic white (69%) but more likely to be multi-racial (8%) than their mothers. Fifty-three percent of the children were female and 61% were firstborn. At the time of data collection, 39% of children were in elementary school and 61% were in middle school; child ages ranged from 8-12 years (M = 10.2 years, SD = 1.6).

Procedures and Measures

The questionnaires were provided by mail or via REDCap to mothers and children based on mother's preference at time of agreement to participate. With the exception of one family, all opted for REDCap completions. Mothers and children who completed and returned the questionnaires each received $10 Target gift cards mailed to their homes.

It is important to note that teachers were not directly contacted, instead families were mailed a separate teacher packet (including teacher consent, questionnaire and a $5.00 Starbucks gift card, along with a pre-paid self-addressed envelope), upon agreement to participate, to share with their child's teacher—either the child's main teacher (elementary school) or science teacher (middle school) unless otherwise requested by the mother. Teachers returned their completed forms by mail to the student investigator at JHSPH (R. Raghunathan).

Data collection included maternal, child and teacher reports of child emotional and behavioral regulation in middle childhood using a single, standardized instrument (Strengths and Difficulties Questionnaire), and three additional questionnaires for mothers focused on sociodemographic data their psychological distress.

Strenghs and Difficulties Questionnaire (SDQ)

Parent, child self-report and teacher versions of the Strengths and Difficulties Questionnaire (SDQ) were used to assess child emotional and behavioral regulation. The SDQ is a focused behavioral screening questionnaire for 4-17 year olds (Goodman, 1997), consisting of 25 questions, with Likert scale responses, organized around five emotional and behavioral constructs; four constructs to measure difficulties (Emotional symptoms, Conduct problems, Hyperactivity/Inattention, and Peer relationship problems), that are summed to generate a composite scale score (Total Difficulties score), and one positive socioemotional construct (Prosocial behaviors). SDQ parent and teacher versions for children aged 4-10 or 11-17 years were sent to informants based on age of child at follow-up; there is only a single child self-report version. All parent, child self-report and teacher versions of the SDQ are analogous in wording of questions and captured constructs.

Maternal Psychological Distress

Women were asked to fill out two separate questionnaires on anxiety and depressive symptoms to index maternal psychological distress.

The State-Trait Anxiety Inventory. State-Trait Anxiety Inventory, Form Y1 (STAI-Y1) is designed to assess state anxiety (Spielberger et al., 1968). The STAI-Y1 includes 20 items relating to current anxiety symptoms, rated on 4-point scales (Spielberger et al., 1968) which, after reverse scoring for some items, are summed. Higher STAI-Y1 scores indicate higher levels of state anxiety.

Center for Epidemiologic Studies Depression Scale. Center for Epidemiological Studies-Depression (CES-D) is a measure of depressive symptoms (Radloff, 1977). Respondents rate how often, over the past week, they experience 20 symptoms that are associated with depression (feeling alone, trouble concentrating, fatigue and restlessness, etc.) on 3-point scales, which are summed. Higher CES-D scores indicate more depressive symptoms (Radloff, 1977).

Data collection procedure and study protocol for this primary data were approved by JHSPH Institutional Review Board (IRB: 00009266).

3.7 Manuscript 3 Analytic Sample, Exploratory Analyses, and Hypotheses Testing

Analytic Sample

Of the 90 eligible families (i.e. had a child within the age range, up to date contact information) 69 women responded and 21 women did not respond. The analytic sample for Manuscript 3, therefore, includes 67 (74%) mothers, 64 (71%) children and 47 (52%) teachers. Percentages reported here reflect response rate. Details of analytic sample derivation and variables used are described in Chapter 6.

Exploratory Data Analysis and Missing Data

Exploratory data analyses examined the distributions of all means of continuous variables and frequency distribution for categorical variables. These analyses tested the normality of variables and informed the use and split of variables into dichotomous and categorical as needed/indicated. For the child self-report SDQ, sensitivity analyses were conducted to determine if there were differences in reporting of behavioral constructs in older (11-12 year old) and younger (8-10 year old) children in the sample. There were no differences in self-reported SDQ constructs between older and younger children (as defined here), therefore no stratified analyses were run. Continuous variables were examined for outliers using histograms. Maternal anxiety and maternal depressive symptoms both had outliers on the upper end of the distribution. Multiple linear regression analyses with and without these outlier values were conducted to test the influence of the outliers on results. Analyses were not sensitive to the outliers and therefore all data on maternal psychological distress was retained as scored.

Missingness was examined for each variable. There were low levels of missingness for the included variables; all variables had no missing values, except parent-reported child age which was missing 2.9% of data. For these cases, child age was imputed from child's age at the time of the 5-year follow-up study and the number of years that had passed since that wave of data collection. For item-level missingness on the SDQ, behavioral and emotional constructs were calculated by summing the items completed and dividing that sum score by the number of valid (completed) items for each construct. Two teachers had 2 items missing from their SDQ reports, respectively. Maternal and child self-reported SDQ did not have any missingness. Similar methods were used to impute values for item level missingness for maternal anxiety and maternal depressive symptoms (n = 2 items missing for one participant on maternal anxiety and n = 1 item missing for same participant on maternal depressive symptoms). Differences in means between imputed variables and dropping cases with missing values on SDQ constructs, maternal anxiety and maternal depressive symptoms did not reveal significant differences, therefore imputed values were retained in analyses to maximize power given the small sample size.

Hypotheses Testing

Manuscript 3 examined the utility of multi-informant approach for measuring child socioemotional development in middle childhood (8-12 years) by comparing and contrasting maternal, teacher and child-self reported behavioral and emotional problems using a well-validated measure, the Strengths and Difficulties Questionnaire (SDQ). The following hypotheses were tested in this dissertation.

Hypothesis 3.1: There will be modest concordance between informants such that mothers and children will report more similarly as compared to mothers and teachers and children and teachers

- ***Dependent Variables:*** mean levels for the 5 SDQ constructs (Emotional symptoms, Conduct problems, Hyperactivity/Inattention, Peer relationship problems, and Prosocial behaviors) and Total Difficulties scores as rated by mothers, child self-report and teachers were examined
- ***Independent Variables:*** selected maternal (age, education) and child covariates (age, sex, birth order, school status) were assessed

Analytic Method

Informant differences (mother, teacher, child) on each of the five SDQ scales and Total Difficulties were tested via paired sample t-tests. Inter-rater associations were examined using Pearson correlation coefficient. Bivariate and multivariable linear regression analyses were utilized to identify maternal (age, education) and child (age and sex) characteristics that explained variation in SDQ reports. Bivariate linear regression analyses were conducted for all maternal, child, and teacher SDQ constructs and Total Difficulties score separately. Adjusted linear regression analyses were conducted for the SDQ Total Difficulties score only.

Example of adjusted linear regression model for SDQ Total Difficulties Score:

$$Y_i = \beta_0 + \beta_{1\ldots2}C_{1\ldots2i} + \beta_{3\ldots5}M_{3\ldots5i} + \epsilon_i$$

$$\epsilon_i \sim N(0, \sigma^2)$$

Where,

Y_i= maternal Total Difficulties Score (or child self-report or teacher report, depending on model)

$C_{1\ldots2}$ = Child characteristics (age, sex)

$M_{3\ldots5}$ = Maternal characteristics (age, education)

Hypothesis 3.2: Maternal and child characteristics, specifically maternal psychological distress, will play a role in explaining discordance between mother, child and teacher reports

- ***Dependent Variables:*** mean levels for the 5 SDQ constructs as rated by mothers, children and teachers and mean differences (deltas) in maternal-child, maternal-teacher, and teacher-child SDQ Total Difficulties scores were the outcomes of interest
- ***Independent Variables:*** maternal psychological distress measures, captured through women's reports of anxiety and depressive symptoms, were the predictor variables
- ***Key Covariates:*** covariates, such as maternal age, maternal education, child age, child sex, birth order, school attendance, for the analyses were selected based on the literature to account for theoretical confounding

Analytic Method

The focus here was on the relationship between maternal psychological distress and SDQ ratings for all informants separately. Bivariate and multivariable linear regression models were fit to assess the relative contribution of maternal and child factors, and maternal psychological distress on informant discrepancies (differences in maternal-child, maternal-teacher and teacher-child Total Difficulties score), separately.

Model fit was assessed for each final linear regression model using residual plots and added variable plots. Influential points were identified and models were re-run without the influential cases to test the validity of the findings. Additionally, sensitivity analyses were performed on a complete case data set (i.e. re-ran final models only for participants who had no item or variable level missingness) to test the impact of data imputation methods on robustness of results. Examining residual and added variable plots generally indicated good model fit for linear regression models (e.g. residuals were somewhat symmetrically distributed towards middle of plot, no clear patterns in fitted vs. predicted values).

Example of multivariable linear regression model to look at informant discrepancies:

$$Y_i = \beta_0 + \beta_{1\ldots2}C_{1\ldots2i} + \beta_{3\ldots5}M_{3\ldots5i} + \beta_8(Depress)_8 + \beta_8(Anxiety)_8 + \epsilon_i$$

$$\epsilon_i \sim N(0, \sigma^2)$$

Where,

Y_i= mother-child Total Difficulties delta (or teacher-child or mother-teacher)

$C_{1\ldots2}$ = Child characteristics (age, sex)

$M_{3\ldots5}$ = Maternal characteristics (age, education)

$Depress$ = maternal depressive symptoms

$Anxiety$ = maternal anxiety

Hypothesis 3.3: Observability of behaviors will explain any differences seen between reporters, such that reporters will agree more on externalizing behaviors and disagree more on internalizing behaviors

- ***Dependent Variables:*** internalizing (Emotional symptoms + Peer problems) and externalizing (Hyperactivity/Inattention + Conduct problems) composites were used based on suggested SDQ scoring (Goodman et al., 2010). U.S normative SDQ scoring bands were used to categorize maternal, teacher, and child self-reports into high internalizing/high externalizing (top 20 percent) or low internalizing/externalizing (bottom 80 percent) groups (Bourdon et al., 2005), which then informed mother-child concordance of defining internalizing and externalizing behaviors (binary: consistent (1)—mother and child defined child the same) vs. inconsistent (0)—mother and child did not define the child the same) as the dependent variable
- ***Independent Variables:*** selected maternal and child sociodemographic characteristics and maternal psychological distress were used as independent variables to examine their contribution to maternal-child discordance in ratings of child internalizing and externalizing behaviors.

Analytic Methods

Testing Hypothesis 3.3 was exploratory and examined concordance on maternal and child reports of child's internalizing and externalizing behaviors and sociodemographic associations using paired t-tests, ANOVA, Kappa statistics for inter-rater agreement. Additionally, the possibility that inconsistencies in mother-child reports could be explained by the observability of behaviors was examined with Fischer's exact test and test of proportions to identify the source of inconsistency (i.e. were mothers reporting more behavior issues than children?).

3.8 Statistical Software for Manuscript 3

Analyses for Manuscript 3 (Chapter 6) were conducted exclusively using Stata version 13.1 (StataCorp., 2013).

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CHAPTER FOUR

Manuscript 1

What Children Do While They Wait: The Role of Motor, Vocal, and Anticipatory Self-Regulation Components in Inhibitory Control

4.1 Abstract

Self-regulatory behaviors are mechanisms through which individuals react or respond to external, day-to-day stimuli and stressors. One important aspect of self-regulation is inhibitory control, often measured and manifested as ability to delay gratification in young children. This study examined the role of spontaneous motor, vocal, and anticipatory behaviors in children's delay ability at age 5, using Walter Mischel's delay task, in a racially and socioeconomically diverse sample of 144 children. Motor activity and anticipation levels played a significant role in a child's delay ability, even after accounting for maternal and child characteristics and sample differences. From the main analysis, three distinct patterns of inhibitory control were identified (*Passive*: low motor activity, low vocalizations, moderate anticipation; *Active*: moderate motor activity, moderate vocalizations, high anticipation; and *Disruptive*: children who were high on all three indicators). Children who were in the *Active* class had lower odds of delaying as compared to children in the *Passive* class, after adjusting for maternal and child characteristics and sample (a*OR* = .12 (*CI*: .05, .30), $z = -4.47$, $p < .001$). Children whose inhibitory control strategies matched their level of anticipation (i.e., *Passive* and *Disruptive* regulators) were able to delay more successfully than children who were mostly driven by anticipation (*Active* regulators). Results indicated that some variation in children's delay ability, age, and use of inhibitory control components (motor activity, vocalizations, anticipation) was explained by sociodemographic differences, specifically maternal age. The findings underscore the

importance of using a person-centered approach to understanding developmental components of children's inhibitory control. Implications of results with respect to classroom behaviors and interventions are briefly discussed.

4.2 Introduction

The early childhood period is characterized by rapid developmental changes within the context of many environmental transitions, one of the most salient being the transition from home environments to formal schooling settings. This transition includes elevated expectations from caregivers and teachers for children to be able to self-regulate behaviors and emotions in order to successfully reach developmental milestones (Liew et al., 2018). The ability to self-regulate is an essential aspect of early childhood development and aides ease of transition into structured settings. Self-regulation is essential for processing emotional arousal, managing impulse control, maintaining positive social relationships, and completing important tasks related to learning, such as focusing and maintaining attention (Blair & Raver, 2015; Blair & Razza, 2007; Eisenberg et al., 2009; Espy et al., 2011; Sethi et al., 2000). Regulation of attention, actions, and emotional expressions tends to have a key underlying requirement: inhibiting an impulsive response in order to activate a more appropriate response. The current study works to disentangle processes underlying children's inhibitory control by assessing how volitional (motor activity, vocalizations) and impulsigenic (behaviors signaling impulses/anticipation, referred to as anticipatory behaviors in this study) processes interact during a delay of gratification task. The goal was to expand the existing knowledge base by using a person-centered approach (latent variable analysis).

Latent variable analysis suggests that an underlying grouping variable (i.e., a latent class variable) may not be explicitly observed/measured but rather inferred from a set of measured indicators. Latent variable analyses allow for a more detailed examination of self-regulation, specifically differential combinations of regulation-related processes, on outcomes of interest. Advantages of a latent variable approach include the ability to organize measured multi-dimensional constructs into classes (or profiles) of self-regulation, therefore allowing for measurement of multiple complex underlying traits and constructs in tandem. The ability to identify and understand latent subgroups within a population allows for the quantification of heterogeneity, often leading to a greater understanding of the population itself via the understanding of individuals who make up latent classes. Latent variable analyses, therefore, provide analytic advantages for answering numerous questions in developmental research on self-regulatory processes (e.g., (Bialecka-Pikul et al., 2018; Hernandez et al., 2018; Huizinga et al., 2006; Moran et al., 2017; Wilson et al., 2009) By examining intraindividual patterns of spontaneous behavioral responses and levels of anticipation during a delay task, this study assesses the mechanisms underlying children's self-regulation and inhibitory control.

Processes Underlying Self-Regulation

Research on self-regulation strategies often focuses on infancy and toddlerhood, as these early years reflect neurological maturation and rapid development of cognitive and emotional regulation processes (Bialecka-Pikul et al., 2018). Distinct self-regulatory capabilities are required at different ages. Infancy is characterized by motor behaviors and vocalizations paralleling less integrated cognitive performance, which gather efficiency and cohesiveness through developmental maturation (Leisman et al., 2016). There is evidence that aspects of cognitive performance (behavioral planning, executive function) develop in tandem with rapid development of motor (movement control and visuomotor coordination) and attentional processes (self-talk, engagement in alternate activities) over time (Grissmer et al., 2010;

Wassenberg et al., 2005). Thus, children's use of planful strategies emerges and advances with the development of cognitive skills. Studies on early self-regulation processes indicate that children are increasingly capable of internal self-regulation by age 5 or 6 years (Raffaelli et al., 2005). As such adaptive strategies solidify, individual differences in behavioral modulation and self-regulation start to emerge, making early childhood a pivotal time for studying underlying self-regulation processes.

There are a variety of deliberate and automatic cognitive and physiological processes involved in the development and employment of self-regulation strategies over time (Supplee et al., 2011). Duckworth and colleagues (2015) propose a *dual influence* framework to characterize processes involved in self-regulation and inhibitory control. Similar models have been proposed and used to examine developmental trajectories in self-regulatory capacity in the literature with various terms/constructs such as reactive vs. effortful control, hot versus cool systems, or relational vs. impulsive dynamics (Blair, 2002; Blair et al., 2011; McGuire & Kable, 2013; Neuenschwander & Blair, 2017; Sethi et al., 2000). Here the focus is on the *dual influence* framework.

This framework distinguishes processes that encourage immediate rewards versus those that encourage waiting for distal goals (Duckworth & Steinberg, 2015). The dual influence framework contrasts volitional, or voluntary behaviors facilitating long-term goals, and impulsigenic, or automatic/involuntary behaviors that are focused on immediate rewards, processes (Duckworth & Steinberg, 2015). Examination of self-regulation should not overlook these two distinguishing features of self-regulation—both the target of the regulation (behaviors or internal states) as well as the extent to which self-regulation behaviors are spontaneous should be carefully examined.

Volitional processes that facilitate goal-directed actions are driven by executive functions; these processes tend to favor persistence (McGuire & Kable, 2013). For example, in the presence of temptations, executive functioning skills allow for a child to keep abstract goals in mind (working memory), voluntarily suppress urges towards the temptation (inhibition), and shift their attentional focus (shifting) in order to achieve the intended goal (Duckworth & Steinberg, 2015; Neuenschwander & Blair, 2017). Therefore, employing volitional processes allows for the suppression of undesired impulses. Beyond executive functioning, volitional processes include metacognitive processes, such as attention deployment strategies (Duckworth & Steinberg, 2015). Specific to inhibitory control, studies have indicated that children wait longer if their attention is diverted away from the reward, if they use self-distraction methods such as fidgeting and self-talk, or employ 'out of sight out of mind' tactics like covering their eyes, removing the reward object from sight or facing away from the reward (Duckworth & Steinberg, 2015; Manfra et al., 2014; Sethi et al., 2000). In the current study, the contribution of different volitional processes (inhibitory control strategies such as motor activity and vocalizations) was examined in order to examine patterns of interactions that facilitate successful delay of gratification.

Impulsigenic processes, on the other hand, relate to automatic or involuntary activation of impulses that facilitate gravitation towards immediate rewards rather than delaying. These processes are oftentimes more reflexive and rooted in rapid decision making (McGuire & Kable, 2013). Measuring the level of temptation that a child has towards a reward is key to understating why some children are able to wait while others are not. Less focus has been placed on quantifying impulsigenic/anticipatory processes. Some researchers have examined impulsigenic processes through physiological measures (Wilson et al., 2009). The current study looks at children's behavioral cues of temptation or anticipation during a delay of gratification task to quantify varying levels of anticipatory behaviors. Based on existing frameworks (McGuire & Kable, 2013; Sethi et al., 2000; Yerkes & Dodson, 1908), it is hypothesized that children who have low levels of anticipation may not be motivated enough to delay, while children with high levels of anticipation are too excited/stimulated to wait; moderate levels of anticipation, therefore, might be optimal to delaying successfully.

Individual differences in self-regulatory behaviors, therefore, reflect the interplay and variation between volitional and impulsigenic processes. The *dual influence* framework provides a practical way to integrate and distinguish between these two forces while laying the foundation for why behaviors vary across children and why some children can wait longer than others, even when faced with temptation. For example, Duckworth et al. (2015) pose that lapses in self-regulation may be due to deficiencies in volitional processes, but might also reflect strong impulsigenic pulls that outweigh volitional processes, supporting self-regulation as a balancing act between internal and external regulatory states.

Importance of Inhibitory Control

Inhibitory control, a component of self-regulation, is defined as the ability to voluntarily regulate behavior, emotions and attention to inhibit a dominant response and activate a subdominant response (Rothbart et al., 2011; Rueda et al., 2005), thus involving dynamic interplay and management of volitional and impulsigenic regulatory processes. The ability to inhibit and modify actions in response to environmental changes and demands is a key aspect of goal-directed behavior (van de Laar et al., 2014). Inhibitory control can be considered a hallmark of child development, relying on coordination of emotional arousal and attention which are often expressed as a range of verbal and non-verbal regulatory strategies (Neuenschwander & Blair, 2017).

Rothbart (1989) pointed to important regulatory capacities that are involved in sustaining inhibitory control including cognitive, social, emotional, motor and behavioral performance. Cross-modal components of inhibitory control, such as motor activity, self-soothing vocalizations and cognitive processing, work together to coordinate responses to stimuli (Rothbart, 1989). Therefore, the capacity to use executive functions to regulate behaviors and emotions is essential to developing inhibitory control. Since children often exhibit a variety of strategies to control impulses, this study focuses on exploring these individual differences as an indicator of socioemotional development.

The role of inhibitory control as a school readiness skill has gained importance over the years (Blair & Raver, 2015). The early childhood years are crucial for the development of self-regulatory capacity, with successful transition into increasingly structured environments (e.g., kindergarten, elementary school) as markers for later health-related and socioemotional outcomes (Allan et al., 2014). Children are repeatedly faced with situations at home, with peers, and in classroom settings, where they need to inhibit or delay actions, comply with requests, and monitor behaviors in accordance to situational demands (National Research & Institute of Medicine Committee on Integrating the Science of Early Childhood, 2000). While many children are able to successfully transition into more structured classroom environments, many children struggle with regulating behavior (Allan et al., 2014). The assessment of inhibitory control through transition periods, such as kindergarten, provides a unique way to examine self-regulatory capacity given changes in situations where the ability to wait is required, and increases in social rules, expectations, and pressure during this time (Simpson & Carroll, 2019;

Wilson et al., 2009). Adaptive development of self-regulation strategies is crucial as transitioning into formal school settings comes with expectations that children can effectively manage themselves.

In addition, there is robust evidence linking poor inhibitory control to later maladaptive psychosocial outcomes, such as increased internalizing behavior problems, anxiety, depression, and to lapses in academic skills such as working memory and executive functioning (Anzman-Frasca et al., 2015; Eisenberg et al., 2001; Kochanska et al., 2000; Lengua, 2002). Thus, work in both developmental and educational domains underscores the necessity of strong inhibitory control for multiple aspects of child development. This study looks at individual differences in behavior employed during a delay task as a vehicle to study inhibitory control and self-regulation during the developmental period housing kindergarten readiness.

Inhibitory Control Strategies and Delay of Gratification

Self-control is an aspect of inhibitory control that facilitates inhibition of undesired impulses in order to favor desired actions (Duckworth & Steinberg, 2015). The alternative to self-controlled behaviors is impulsivity which often brings short-term gratification, but frequently at the expense of long-term goals. As a result, self-control is often conceptualized and measured through tasks that challenge delay of gratification during child development (Duckworth & Steinberg, 2015; Sethi et al., 2000).

Delay of gratification reflects a child's ability to wait for a delayed reward instead of taking the immediate and/or lesser reward. Seminal research starting in the 1970s explored experimentally-directed delay strategies such as prompting children to think about rewards in a non-enticing manner, encouraging children to think of fun/abstract thoughts as a method of distraction and removing rewards from view/providing other distractions (i.e. toys) (Grolnick et al., 1996; Mischel et al., 1989; Mischel et al., 1972; Mischel & Moore, 1973). Walter Mischel's experimental work set the stage for examining children's delay of gratification ability, popularized as the Marshmallow Test (Mischel et al., 1989). Delaying gratification has been repeatedly measured in childhood and used to predict a host of outcomes, such as reward-seeking behaviors, academic achievement, and socioemotional development in adolescence and even in adulthood (Hernandez et al., 2018; Supplee et al., 2011; Watts et al., 2018). This study is focused on the processes underlying delay of gratification, rather than the predictive ability and behavioral correlates of the construct itself. Delaying gratification is largely driven by one's executive functioning, with a focus on voluntary inhibition of dominant responses (inhibitory control), and flexibility and attention modulation (shifting) (Miyake et al., 2000). By unpacking the various components underlying delay of gratification, it is possible to both understand more about children's development as well as tailor interventions to maximize self-regulatory potential.

Extant research on delay of gratification has focused on one's ability to delay versus not delay within the experimental task. Differences in delay ability have been attributed to numerous child characteristics such as sex, age, and temperament (Dalimonte-Merckling & Brophy-Herb, 2019; Hong et al., 2017; Li-Grining, 2007), and maternal characteristics as a proxy for family and sociodemographic context such as maternal education, age, and psychosocial distress (Li et al., 2017; Li-Grining, 2007; Ng-Knight & Schoon, 2017; Riis et al., 2016). The role of maternal and child characteristics in development of children's inhibitory control and delay ability to date is largely mixed.

Less focus has been placed on analyzing how and why certain children are able to delay gratification as compared to others. The ways that children attempt to delay gratification manifests in behaviorally heterogeneous verbal and non-verbal manners suggesting differences in motivational and regulatory systems (Murray et al., 2016; Neuenschwander & Blair, 2017; Wilson et al., 2009). Even when children successfully delay, there is variation in what children do during the waiting period. Therefore, exploring factors that go into children's ability to delay gratification allows for a better understanding of the self-regulatory processes at play than total wait time alone.

Recent studies have shown that behaviorally observable differences (i.e., attention/gaze towards reward, averting gaze, fidgeting) are associated with differences in self-regulation profiles that predict later socioemotional development (Wilson et al., 2009). Experimentally-directed strategies have also recently been examined by asking children to imitate self-regulatory strategies from adults (Corriveau et al., 2016), and exposing children to a storybook character who sees willpower as energizing (Haimovitz et al., 2020). Studies like these bolster the concept that a range of attentional and cognitive strategies, including in the form of self-distraction, facilitate longer delay ability by moderating temptation and focus towards the reward.

Developmental researchers have long studied the relationship between attention deployment strategies (also referred to as coping strategies) and the ability to deal with stressful situations in early life. Research on self-regulation in infancy and childhood should not only focus on the target of the regulation (i.e., behavior or internal states), but also the extent to which self-regulation is spontaneous, rather than directed, to truly understand patterns of distinguishable behaviors that provide insight into child development (Bialecka-Pikul et al., 2018). There have been empirical evaluations of child-directed, or spontaneous, strategies used to regulate emotions in infancy and toddlerhood (e.g., (Bialecka-Pikul et al., 2018; Supplee et al., 2009), with less focus on developmental transition periods such as preschool or kindergarten years. Selected studies examining spontaneous self-regulation strategies used specifically to delay gratification in early childhood are highlighted.

Anticipatory Behaviors and Delay of Gratification

Rodriguez et al. (1989) conducted one of the first studies to examine spontaneous inhibitory control strategies during the Marshmallow Test (Mischel et al., 1989), in a sample of boys (ages 6-12 years) at high risk for socioemotional problems. The goal was to examine observable attention deployment strategies and the relationship with delay ability by looking at the focus of attention (towards reward/test materials or elsewhere) through anticipatory behaviors such as looking, touching and talking directed at the reward/test materials. Results of this study indicated that children who distracted themselves by directing their attention away from test materials, subduing their anticipation towards the reward, were able to wait longer than children who were focused on the reward during the duration of the task.

The behavioral coding scheme for strategic attention deployment used by Rodriguez et al. (1989) was adapted to examine the relationship between coping strategies toddlers use when separated from their mother and attentional strategies during delay of gratification at age 5 (Sethi et al., 2000). Specific strategies (attention towards test materials, attention away, self-distraction) were coded and mapped onto 'hot' attentional focus (i.e., proportion time child spent looking at reward) versus 'cool' focus (self-distraction away from reward). Early strategies for coping with maternal separation predicted the type of strategies children used during the delay of gratification task; toddlers who were able to use self-distraction techniques when separating from their mother were able to delay gratification using 'cool' strategies at age 5 (Sethi et al., 2000), indicating some stability and continuity in self-regulation strategies over time. Several other research groups have replicated such findings in early childhood (i.e., (Jahromi et al., 2019; Murray et al., 2016; Peake et al., 2002; Pecora et al., 2014)).

Supplee and colleagues (2011) conducted a longitudinal analysis of emotional self-regulation strategies in a sample of low-income boys from a large metropolitan area, who were at risk for developing conduct-related problems. Delay of gratification assessments were repeated at ages 2, 3, and 4 years, coding for emotion-focused active strategies (self-soothing), emotion focused passive strategies (direction attention away, blank stares), planful strategies (engaging in other behaviors, wandering around the room) and level of focus/perseveration on delay object, expanding on prior work done in attention-related strategies by incorporating a wider range of observable behaviors. Uniquely, Supplee et al. (2011) utilized both variable and person-centered analyses to examine developmental trajectories in emotional self-regulation strategies. Both variable and person-centered analyses found that children initially used more emotion-focused strategies (comfort seeking) and transitioned into greater use of planful strategies (distraction or wandering around room) with time (Supplee et al., 2011). Supplee and colleagues focused not only on examining how emotion regulation strategies related to delay ability, but rather on understanding trajectories of strategies used in a sample of boys at high risk for conduct disorders (Supplee et al., 2011).

Vocalizations and Delay of Gratification

Very few studies have looked at the role of spontaneous vocal/verbal self-regulation strategies and delay ability, despite the role of verbalizations in executive function (cognitive control) and learning-related tasks (Manfra et al., 2014). Early work on verbalizations and self-control has been dedicated to instructed use of strategies, where the experimenter suggests the child to use temptation-inhibiting verbalizations (e.g., “I am not going to play with the toy”) or verbalizations about the task rules to improve children's ability to inhibit their impulses. One study examined preschool-aged (3 to 4 years) children's spontaneous motor movement and verbalizations during a resistance-to-temptation task to parse motor and verbal components, rather than strategic attention deployment alone (Manfra et al., 2014). Behaviors were coded for frequency and duration of touches, motor movements, and verbalizations. Results of the study indicated that children who used motor, verbal, or a combination of strategies during the task were able to resist temptation longer than children who did not use such strategies (Manfra et al., 2014). The results suggest motor or verbal strategies could be effective in increasing self-control and likely a combination of multiple strategies is optimal

Motor Activity and Delay of Gratification

A handful of studies have specifically examined motor activity as a regulatory component in relation to strategies used during delay of gratification tasks. Most studies have relied on maternal report of motor activity as a temperamental construct, rather than explicitly measuring and observing motor activity levels during the delay task itself (Duckworth et al., 2013; Mittal et al., 2013; Peake et al., 2002). How well children perform in a delay of gratification task might relate to skills/strategies that are founded in three commonly assessed dimensions of temperament: activity (motor activity levels), sociability (closeness to others), and emotionality (intensity of emotions) (Hong et al., 2017). Duckworth and colleagues (2013) found that maternal ratings of their children's (average age 4 years) motor activity, gauged via Child Behavior Questionnaire, were associated with delay ability; higher maternal ratings of child motor activity were related to lower delay time (Duckworth et al., 2013). Similarly, Mittal et al (2013) found that preschool-aged children who were non-delayers were more likely to have higher reported activity levels than children who were able to delay longer (Mittal et al., 2013).

In 9-year-old children, Hong et al. (2017) examined the interaction between maternal ratings of temperament dimensions and observed strategies children used during a delay task. The study combined previous research done on spontaneous attention deployment strategies, such as averting attention to reward, attention towards reward, manipulation (touching, spinning) the test materials and abstractive imagination (i.e., pretend-play), and maternal report of motor activity levels (Hong et al., 2017). Children who had high maternal-rated temperamental activity levels were less able to delay; however, a child's use of self-regulation strategies moderated this relationship. For children who used a more effective strategy (i.e., averting attention to reward), there was no relationship between activity levels and delay ability, but for children who used a less effective strategy (i.e., directing attention towards reward), higher temperamental activity was associated with shorter delay time. Taken together, effective self-regulation strategies may help children with higher temperamental activity levels delay longer.

A study examining fidgeting as an arousal regulation strategy suggested that moderate levels of fidgeting may be optimal for waiting for a reward (Neuenschwander & Blair, 2017). This study explicitly measured the role of regulatory (volitional) and motivational (impulsigenic) components on delay ability in children ages 5 to 9 years. This was the first study to look at anticipation behaviors and spontaneous engagement in self-control strategies, specifically fidgeting/motor activity as a form of arousal/anticipation control during a delay task, to date. Anticipation levels were curvilinearly associated with delay time, with spontaneous engagement in self-control strategies, such as fidgeting, and child's executive functioning moderating this relationship (Neuenschwander & Blair, 2017). Spontaneous engagement in self-control strategies was important for children with low executive functioning but was not related to delay ability for children who had higher executive functioning (Neuenschwander & Blair, 2017). The results of the study support a model that explains motor activity in terms of Yerkes and Dodson's (1908) inverted-U relation between arousal and performance/temptation (Yerkes & Dodson, 1908). That is, high and low motor activity levels were related to less ability to delay gratification while moderate activity levels were a beneficial regulatory strategy for some children. Findings from Neuenschwander and Blair (2017) largely motivated the current study methodology. The inclusion of vocal self-regulation, in addition to motor and anticipation behaviors, in a larger, more diverse sample of children extends upon prior work.

The Current Study

Based on theoretical and empirical knowledge, there is an interaction between impulsigenic and volitional capacities that explains how anticipatory/attention deployment, non-verbal and verbal behaviors come together in regulating impulses. There is no guarantee that the impulse to indulge in an immediate reward is the same for all children (Duckworth & Steinberg, 2015), therefore failing to assess or control for this through measuring anticipatory behaviors may result in capturing a partial picture of a child's regulatory capacity. Thus, a measure for anticipation towards reward in addition to motor activity and vocal behaviors is included. Also, the intensity of inhibitory control strategies is explored to capture individual differences on a continuum rather than only the presence/absence of strategies used, as several of the reviewed studies have done.

To my knowledge, no study has examined spontaneous use of motor activity, vocalizations, and anticipation in tandem during a delay of gratification task in early childhood using a person-centered approach. Although the development of internal regulation via inhibitory control is considered a universal aspect of child development, much of the extant research focuses on middle class racial/ethnic majority children (Skowron et al., 2014). The current study extends previous literature by evaluating differential processes underlying children's ability to wait in a racially and socioeconomically diverse sample.

This study intends to expand on the wealth of studies examining delay of gratification by focusing on specific strategies that children use to provide a more detailed picture of inhibitory control and self-regulation in children 5 years of age by: 1) characterizing the use of motor, vocal, and anticipatory behaviors during a delay of gratification task and associated maternal and child characteristics, 2) examining the role of these inhibitory control components in predicting children's delay ability, 3) deriving patterns of motor, vocal, and anticipatory behaviors using a person-centered approach, and 4) considering whether different patterns inhibitory control behaviors help or hinder delay ability.

4.3 Methods

Participants

Participants for this study include a sample of families who originally participated in a study that commenced during the prenatal period who were followed up when children were 5 years old (referred to as the *prenatal sample*) and an additional sample of mothers and their 5 year old children from that same local area but drawn specifically from residents of a large urban center (referred to as the *community sample)* (Riis et al., 2015).

Prenatal Sample

The prenatal sample was recruited between 2006 and 2007 and followed up between 2011 and 2012. Enrollment was limited to low-risk, non-smoking women with healthy, singleton pregnancies (see (DiPietro et al., 2010) for further details). Data were collected from 57% of eligible maternal-fetus pairs (*n* =128) from the prenatal sample, resulting in laboratory-visit data for 58 mother-child pairs and 15 mothers who participated remotely via mail surveys.

Community Sample

In order to expand the sample to capture a wider range of family circumstances and sociodemographic characteristics, mother-child pairs were recruited from Baltimore City through community postings and fliers around the city (e.g., community centers, churches, markets). To be eligible for participation, mothers had to be either the biological mother or legal guardian of the child, and fluent in English. The *community sample* included laboratory data collected from 93 mother-child pairs.

Children in both samples were ineligible if their mothers reported significant health conditions or developmental disabilities that impaired the child's cognitive, motor, or regulatory functioning. 151 mother-child dyads participated in laboratory visits. Of the 151 children who attended laboratory visits, 54 from the prenatal sample and 90 from the community sample had participated in the delay of gratification task (*n* = 3 had incomplete visits/did not complete delay of gratification task (all in *community sample), n* = 4 with no video data (all in *prenatal sample*)). The current analyses use data from 144 children with complete delay of gratification task data.

Sample Characteristics. Table 4.1 describes and compares sociodemographic characteristics for mother-child dyads in the *prenatal* and *community* samples. Mothers in the *prenatal* sample were on average older, had completed more years of education, and were more likely to be married than mothers in the *community* sample. Mothers in the *community* sample were more likely to be Black while mothers in the *prenatal* sample were more likely to be non-Hispanic white. Children in the *community* sample were slightly older than children in the *prenatal* sample. Children's race and ethnicity matched mothers' race and ethnicity composition for each sample. There were no differences in child sex or school attendance between children in the samples (Table 4.1).

Procedures and Measures

Study visits were conducted in a dedicated testing space. Visits lasted approximately 90 minutes during which children engaged in a battery of tasks to assess cognitive and executive functioning and emotional regulation. All tasks were audio/video recorded. At the same time, mothers completed questionnaires on themselves and their child's behavior and development in a separate room.

Delay of Gratification Task

The study protocol employed the standard Delay of Gratification/Marshmallow test (referred to as delay task here) as developed by Mischel and colleagues (Mischel et al., 1989). This task is developmentally appropriate to assess inhibitory control and has been shown to challenge behavioral and emotional regulation in young children (Mischel et al., 1989; Watts et al., 2018). Children were seated with a bell in front of them and asked to select a snack of their choice (marshmallow or pretzel). The child was told that the research assistant (RA) would leave the room for some time and to not eat the snack until the RA returned. The child was also instructed that ringing the bell would bring the RA back into the room and allow for him/her to eat the snack; however, if he/she waited for the RA to return on their own (without child ringing bell), he/she would be rewarded with two snacks, if not, he/she would get to eat the one snack in front of them. The child was left alone for eight minutes or until he/she rang the bell to bring the RA back.

Inhibitory Control Components Coding

Delay ability (waited vs. did not wait for the full 8-minute task time) had been previously coded for the delay task. Additional codes surrounding motor, vocal, and anticipatory self-regulatory strategies were introduced for the current study to assess individual differences that contribute to ease or difficulty in delaying. Interval coding (every 30 seconds) of audio/video coded the presence and degree of motor behaviors and vocal self-regulation. Partial interval coding was employed with a decision rule such that only behaviors that occurred for the majority of the interval (at least 16 seconds) were recorded for each interval. This was in effort to capture the most dominant behavior during the interval and account for over and underestimation that often occurs with other methods of discontinuous data collection. Because a child could exhibit behaviors from multiple categories at the same time, motor and vocal self-regulation behaviors were coded for separately. Therefore, each interval has two behavior codes, but only one code from each category of motor or vocal behaviors, respectively. A global code for level of anticipation was included after viewing the videos.

A primary coder scored every video. Twenty percent of videos were double coded by a trained RA to establish reliability in self-regulation coding. Disagreements in ratings were resolved through discussion. Cohen's kappa was used to determine if there was agreement between raters' classification of child self-regulatory behaviors. Weighted kappa was used to account for differing degrees of disagreement between raters on categories of self-regulatory behaviors.

The coding schemes were based on previous behavioral rating systems for inhibitory control tasks (Goldsmith & Rothbart, 1999) and observations of child behavior from task videos. Detailed coding schemes for motor, vocal, and anticipatory behaviors are in Appendix A. Tasks that ran longer than 480 seconds due to errors in protocol were truncated at 480 seconds (i.e., if the child waited the 480 seconds, they were considered to have delayed the whole time).

Motor Activity. For the first pass of 30-second interval coding, degree of motor behaviors was coded on a scale of 1 to 3 as no/low motor activity (sitting still, discrete movements), moderate motor activity (fidgeting constantly, moving head/arms/legs), and high motor activity (kicking legs, clapping hands, up and down in chair). Intervals were coded as "not codable" if the child was out of camera view. One motor behavior category was coded for each interval. There was substantial agreement between the two raters for motor self-regulation behaviors, $\kappa = .78$, $p < .001$. A continuous composite score for mean level of motor behaviors was created by summing the levels of motor behaviors during task time and dividing the sum score by the number of intervals that the child waited. This was used to define degree of motor inhibition/self-regulation during the task.

Vocalizations. For the second pass at the video recorded tasks, degree of vocal self-regulation was coded on a scale of 1 to 3 as no/low vocalization (no audible mouth movements or vocalizations), moderate vocalization (quiet self-talk, sighing), and high vocalization (singing, yelling). Again, only one vocalization category was coded for each interval. There was excellent agreement between the two raters for vocal self-regulation $\kappa = .88$, $p < .001$. A continuous composite score for mean level of vocal self-regulation was created as was done with motor behaviors. This was used to define degree of vocal self-regulation during the task.

Anticipation. A global score for the anticipatory component of self-regulation was assigned for each child after reviewing the task. Anticipation towards the snack reward was coded categorically on a scale of 1 to 3 as no/low anticipation (spacing out, no visible signs of frustration), moderate anticipation (gazing intensely at test materials, picking up snack, consistent sighing), and high anticipation (repeatedly picking up/playing with snack, smelling snack, visible frustration or excitement). This was to assess level of observable temptation/anticipation that the child had towards the snack reward, and to examine in tandem with the self-regulatory strategies the child uses to quell his/her overall temptation and anticipation towards the snack reward. There was substantial agreement between the two raters for vocal self-regulation $\kappa = .78$, $p < .001$.

Maternal and Child Covariates

Key covariates were selected based on prior literature on confounders of inhibitory control and child self-regulation development (e.g., (Power et al., 2016; Watts et al., 2018). The following maternal and child level covariates were evaluated in this study.

Maternal and Child Characteristics. Maternal age, education, marital status, race and ethnicity were collected through maternal report. Child age, sex, race, ethnicity and whether or not the child attended pre-K or Kindergarten were also collected through maternal report. Given the fact that the delay of gratification task specifically uses a snack as a reward, and the growing body of literature on snack delay tasks and children's BMI (see (Caleza et al., 2016) for review), child body mass index (BMI) as a confounder was accounted for. Child height and weight measured at the study visit was used to compute age and sex-adjusted BMI. Categorical weight status (underweight/healthy or overweight/obese) was assigned for each child based on the Center for Disease Control (CDC) guidelines for age and sex adjusted BMI percentile cut-offs (*Healthy Weight: About Child & Teen BMI.*, 2018).

Maternal Psychosocial Distress. Based on prior work, a maternal distress factor score was used in the analyses (for details on factor analysis see (Riis et al., 2016)). This composite score was comprised of the following measures: 1) State-Trait Anxiety Inventory (STAI), designed to assess state and trait levels of anxiety (Spielberger, Gorsuch, & Lushene, 1968); 2) Center for Epidemiological Studies- Depression (CES-D), a measure of depressive symptoms (Radloff, 1977); and 3) Parenting Stress Index, Fourth Edition Short Form (PSI-SF), measuring three domains of parenting-related stress including parental distress, parent-child dysfunctional interaction, and difficult child which combine into a Total Stress scale (Abidin, 2012). Higher scores for this variable indicated higher levels of maternal distress.

Child Receptive Language. Children's Peabody Picture Vocabulary Test (PPVT) was administered during the lab visit. The PPVT was used to measure receptive language as a proxy for verbal intelligence (see (Protzko, 2015). Prior research has shown the importance of verbal intelligence for self-regulation skills (Binns et al., 2019; Blair, 2002; Blair et al., 2011). The Delay of Gratification task relies on children's abilities to comprehend and follow the rules presented to them. Therefore, to account for children's verbal intelligence PPVT scores were used (standardized *within* the sample) as a potential confounder.

Data Analyses

Descriptive and exploratory analyses (t-tests, χ^2 tests, Pearson correlation coefficient, and ANOVA/ANCOVA) were conducted to examine differences in selected covariates (maternal education, maternal age, child sex, child age, child BMI, child school type, maternal distress, children's PPVT scores and a variable to indicate whether children were from the *prenatal* or *community* sample (sample indicator)) between children who delayed the full task time and children who did not delay. Theoretical confounders such as maternal age, maternal education, child sex, child age, child BMI and sample indicator were retained in all adjusted analyses. For the remainder of potential covariates (i.e., maternal distress, child PPVT score), only those that reached a cutoff of $p < .10$ were retained to adjust for empirical confounding. As there were substantive differences in sample characteristics between the *prenatal* and *community* samples, multicollinearity between sociodemographic variables and sample indicator were checked using variance inflation factors (VIF).

Bivariate and multivariate logistic regression models were used to look at the relationship between motor activity, vocalizations, and anticipation and delay ability. Selected covariates were added in a step-wise manner. Multivariate logistic regression models were evaluated for model fit using model fit statistics and diagnostics (i.e., χ^2 goodness of fit, Akaike Information Criterion (AIC), Bayesian information Criterion (BIC)).

Latent class analysis was used to examine differential patterns of child inhibitory control classes during the Delay of Gratification task. To index inhibitory control, motor activity and vocalizations composite scores were entered as continuous variables, where higher scores indicated higher levels of observable motor activity and audible vocalizations, respectively; anticipation was a categorical variable with dummy variables for moderate anticipation (yes vs. no) and high anticipation (yes vs. no) used to fit the latent model. One-, two- and three-class models were fit for the four listed indicators.

Starting with a 1-class model, classes were added sequentially without covariates and examined for fit (Nylund et al., 2007). Information criterion (BIC, sample size adjusted-BIC, AIC) were used to determine model fit during class enumeration, with lower values indicating better model fit. Lo-Mendell-Rubin (LMR) and Bootstrap Likelihood Ratio (BLRT) tests, and associated *p*-values, were examined to assess whether addition of classes improved or detracted from the model. Entropy was also examined to assess class specification. Full information maximum likelihood (FIML) estimation was used to handle missing data. To test for maternal and child characteristics that may contribute to differences in child inhibitory control, selected covariates were regressed onto the final class enumeration model. Inhibitory control classes based on posterior class probabilities, from the final class enumeration model, were used as predictors of delay ability using bivariate and multivariate logistic regression analyses along with selected maternal and child characteristics.

Class enumeration was conducted in *Mplus* software version 8 (Muthén & Muthén, 1998-2017). All other analyses were conducted using Stata statistical software version 16.1 (StataCorp, 2019).

4.4 Results

One hundred thirty-three children had codable inhibitory control data (n = 53 *prenatal*, n = 80 *community*). The remaining 11 children ate the snack reward immediately upon presentation and therefore did not have audio/video recorded data to code. Since these analyses focus on inhibitory control strategies, they were limited to children with at least one interval of codable data. Table 4.2 compares differences in covariates between children who delayed the full time (delayers, n = 89) versus children who did not delay the full time (non-delayers, n = 44). Overall, mothers of delayers were older than mothers of non-delayers. No other differences in maternal characteristics or maternal distress score were detected between delayers and non-delayers. Children who delayed were more likely to be underweight/normal weight as compared to non-delayers who were more likely to be obese/overweight. There were no other differences in child characteristics or PPVT score.

Based on the set cutoff point of $p < .10$ for including empirical covariates while taking theoretical covariates into consideration, maternal age, maternal education, child age, child sex, and child BMI were retained. Since there was no difference in the ability to delay when comparing the *prenatal* and *community* samples the samples were combined. An indicator for study sample was included in all analyses due to the significant contrasts in sociodemographic characteristics (refer to Table 4.1), to account for non-measured/non-measurable differences between the two samples. Examining variance inflation factors elucidated that maternal age, maternal education and sample indicator were not collinear (mean VIF = 1.38), and therefore all were retained in multivariable models.

Sociodemographic Moderating Influences on Inhibitory Control Components

No significant associations were detected for motor activity, vocalizations and anticipation with maternal age, maternal education, child age, child BMI, or study sample. Child sex was associated with motor activity such that boys (M = 1.69, SD = .53) exhibited greater motor activity than girls (M = 1.48, SD = .43), $t(131) = -2.55$, $p = .01$. No other sex differences were detected. It is worth noting that almost all of the 11 children who ate the snack upon presentation, and thus are not included in these analyses, were boys (n = 9).

Multiple linear regression models and analyses of covariance (ANCOVA) were used to examine the adjusted relationship between maternal, child and family characteristics and inhibitory control components. Separate linear regressions were run with motor activity and vocalizations as outcomes. ANCOVA was used to examine adjusted associations with anticipation. The selected maternal and child covariates did not explain a significant proportion of variance for motor activity, vocalizations or anticipation. However, child sex remained significantly associated with motor activity after adjusting for maternal and child characteristics and sample, $b = -.21$, $t(120) = -2.40$, $p < .05$. There were also significant differences for vocalizations between children in the *prenatal sample* as compared to the *community sample* after adjusting for covariates, such that children in the *prenatal sample* had higher levels of vocalizations than children in the *community sample*, $b = -.30$, $t(120) = -2.08$, $p < .05$. Results of ANCOVA indicated no associations between the covariates and anticipation level.

The Role of Motor Activity, Vocalizations and Anticipation in Delay Ability.

Descriptive analyses (i.e. t-tests, χ^2 tests, ANOVA) showed delayers having lower motor activity and low or moderate anticipation compared to non-delayers; there was no difference in vocalizations between delayers and non-delayers. Motor activity and vocalizations were moderately correlated, r (131) = .35, $p < .001$. There were differences in motor activity, F (2, 130) = 25.0, $p < .001$, and vocalization, F (2, 130) = 6.24, $p < .01$, by level of anticipation; children who showed high anticipatory behaviors as compared to low anticipatory behaviors were more likely to display higher levels of vocalizations, while children who had moderate and high levels of anticipation had higher levels of motor activity as compared to children with low anticipation.

Initial separate simple logistic regression models were fit to look at unadjusted associations between each inhibitory control component and delay ability. Next, selected covariates were added in a step-wise manner starting with maternal characteristics, then adding child characteristics, and finally adding an indicator to control for the different samples (*prenatal* vs. c*ommunity*). Final multivariate logistic regression models were selected based on model fit statistics and diagnostics (i.e., Hosmer-Lemeshow test, AIC, BIC).

Unadjusted logistic regressions confirmed that motor activity was significantly associated with delay ability, OR = .25 (CI: .11, .56), z = -3.36, p = .001, such that for every unit increase in motor activity level, children were about 75% less likely to delay the full task time. There was no unadjusted association between vocalizations and delay ability. Children with low anticipation were about 9 times more likely to delay than children with high anticipation, OR = 9.04 (CI: 2.5, 33.3), z = 3.31, p = .001. Similarly, children with moderate anticipation were almost 6 times more likely to delay as compared to children with high anticipation, OR = 5.6 (CI: 2.2, 13.9), z = 3.7, $p < .001$.

Multivariate logistic models were run with covariates next. Models with maternal and child covariates, excluding sample indicator, had the lowest AIC and BIC. However, the difference in AIC and BIC between models excluding and including the sample indicator were not significant. Goodness-of-fit tests assessing whether the observed sample data represent data that would be expected at the population level indicated that fully adjusted models (including sample indicator) still fit the data well. Therefore, to ensure proper adjustment for potential confounders, all covariates were retained.

After adjusting for maternal and child characteristics and study sample, motor activity remained a significant predictor of delay ability, a*OR* = .26 (CI: .10, .65), $z = -2.86$, $p < .01$; children who had higher average motor activity were less likely to delay. There remained no significant association between vocalizations and delay ability. Similar to bivariate results, children with low anticipation or moderate anticipation were more likely to delay than children with high anticipation, a*OR* = 9.64 (CI: 2.4, 38.2), $z = 3.22$, $p = .001$; and a*OR* = 4.9 (CI: 1.8, 13.1), z = 3.19, $p = .001$, respectively. Sociodemographic findings from bivariate analyses remained in the fully adjusted models.

Latent Class Analyses: Patterns of Inhibitory Control

Latent class analysis was used to examine patterns of inhibitory components in tandem and to distribute children into inhibitory control groups. Motor activity and vocalizations were examined as continuous composite scores and dummy indicators for moderate (yes vs. no) and high (yes vs. no) anticipation were used. Figure 4.1 illustrates the latent variable diagram.

Class Enumeration

Fit statistics for class enumeration process are listed in Table 4.3. Based on the number of indicators used, 1-, 2-, and 3-class models were fit. Fit statistics indicated that a 3-class model was most appropriate to characterize child inhibitory control classes. In general, the BIC and AIC decreased from the 1-class to the 3-class model. The distribution of the total sample that fell into each class and the classification probabilities also indicated that a 3-class model optimized class specification, although the entropy was slightly lower in the 3-class model as compared to the 2-class model. Although the third class only comprised 8.3% of the sample, considering the small sample size and substantive interpretations of each class, a 3-class model was ultimately selected.

Child Inhibitory Control Classes

Latent class analysis revealed three distinct classes of child inhibitory control (Table 4.4). Children in class 1 (n = 69) had relatively lower motor activity and vocalizations with moderate levels of anticipation, the "*Passive*" inhibitory control class. Children in class 2 (n = 53) exhibited relatively moderate motor activity and vocalizations, but had high levels of anticipation, the "*Active*" inhibitory control class. Children in class 3 (n = 11) had the highest motor activity and vocalizations and high levels of anticipation, the "*Disruptive*" inhibitory class. Figure 4.2 shows the distribution of children in the defined inhibitory control classes by average motor activity, vocalizations, and anticipation levels.

Sociodemographic Factors Relating to Differences in Child Inhibitory Control Classes. To examine maternal, child, and sample characteristics that relate to distinct classes of child inhibitory control, selected covariates were regressed on identified classes. There were no differences in inhibitory class distribution by study sample ($X^2(2) = 1.29$, p =.52). None of the selected maternal and child characteristics (maternal age, maternal education, child age, child sex, or child BMI category) or sample indicator (*prenatal* vs. *community*) differed when comparing *Passive* vs. *Active*, *Passive* vs. *Disruptive*, and *Active* vs. *Disruptive* classes.

Patterns of Child Inhibitory Control and Delay Ability

Descriptive statistics indicated that 87% of children in the *Passive* class were able to delay the full time, while about 42% and 64% of the *Active* and *Disruptive* classes were able to delay the full time. Bivariate and multivariate logistic regression models were fit to assess whether child inhibitory control class was associated with relative delay ability (odds of delay); the *Passive* class was used as the reference group for the subsequent analyses since almost all children waited in this class. Unadjusted logistic regression analyses revealed that children who were in the *Active* class had lower odds of delaying as compared to children in the *Passive* class, $OR = .11$ (CI: .04, .26), $z = -4.94$, $p < .001$. There was no difference in delay ability between the *Disruptive* and *Passive* classes following adjustment.

Results of the multivariate regression model are presented in Table 4.5. Children in the *Active* class still had lower odds of delaying as compared to children in the *Passive* class, after adjusting for maternal and child characteristics and sample, a$OR = .12$ (CI: .05, .30), $z = -4.47$, $p < .001$. Here, maternal age was related to delay ability after controlling for inhibitory control classes, maternal education, child characteristics and sample, a$OR = 1.1$ (CI: 1, 1.2), $z = 1.98$, $p = .05$; children whose mothers were older were more likely to delay the full time compared to children whose mothers were younger. There remained no significant associations in odds of delaying between *Disruptive* and *Passive* classes. The results were not sensitive to the choice of reference group. A sensitivity analysis comparing the results to models that used either the Active or Disruptive class as the reference group generated similar results.

4.5 Discussion

The current study uniquely expands on existing delay of gratification literature by examining various impulsigenic and volitional processes underlying inhibitory control in early childhood using a person-centered approach. Overall, children who delayed gratification exhibited low to moderate levels of motor activity and anticipation of a snack reward as compared to children who did not delay the full task time. Level of vocalizations did not seem to be associated with children's delay ability even though motor activity and vocalizations were moderately correlated. There were differences in both components by level of anticipation; children who had higher levels of anticipatory behaviors were also more likely to display higher levels of motor activity and vocalizations, in general. Analogous direction and magnitude of the associations remained between motor activity and delay ability and anticipation and delay ability after adjusting for maternal, child, and sample characteristics. The large confidence intervals seen in the relationship between anticipation levels and delay ability suggest interpreting these results with caution. Although vocalizations were not associated with delay ability, controlling for this component resulted in associations among child sex, maternal age, and delay ability. Adjusting for vocalizations revealed that girls were more likely to wait the full task time as compared to boys. Here, children with older mothers were also more likely to wait. Similarly, maternal age was associated with child's delay ability after controlling for level of anticipation.

To disentangle the interplay between volitional and impulsigenic processes driving child inhibitory control, a person-centered approach (latent variable analysis) was utilized. Three distinct classes of inhibitory control were identified: *passive* regulators, who had lower motor activity and vocalizations but moderate anticipation, *active* regulators who had moderate motor activity and vocalizations but high anticipation, and *disruptive* regulators who had high levels of all three components. Maternal, child, and sample characteristics were similar across the three classes. Almost all of the children in the *passive* class were able to delay gratification. Children who were *active* regulators were about 88% less likely to delay the full task time as compared to children who were *passive* regulators, even after controlling for maternal, child, and sample indicators. There were no differences in delay ability between *passive* and *disruptive* regulators, even when changing the reference group in analyses. Again, after controlling for inhibitory control class, maternal age was significantly associated with child's delay ability.

While children use differing levels and combinations of motor activity and vocalizations, anticipation seems to primarily drive the link to children's delay ability. Although analyses did not identify a class of children who expressed low anticipation in this sample, moderate levels of anticipation that were subdued with motor and vocal regulation strategies led to successful inhibitory control. Interestingly, even children with high levels of anticipation were able to delay gratification longer if their level of inhibitory control strategies matched their level of anticipation. It is important to note the small sample size in the *disruptive* class; replication of study methods in a larger sample is needed. Children struggled when there was discordance between level of motor and vocal strategies and level of anticipation; children who had high levels of anticipation, but perhaps not the matching level of self-regulatory strategies to manage their anticipation (i.e., the *active* class), were not able to delay gratification.

Children who were able to delay the full task time were less likely to be overweight/obese as compared to non-delayers. Recent research has shown that successfully delaying gratification in childhood predicts childhood and adult BMI outcomes (e.g., (Bruce et al., 2011; Hughes et al., 2015; Schlam et al., 2013). One group of researchers established that effective early self-regulation strategies, such as shutting out stimuli and distraction, during delay of gratification tasks not only enabled children to wait longer, but also related to eating-regulation strategies, resulting in lower levels of obesity later in childhood (Power et al., 2016). Power et al. (2016) looked at similar components of inhibitory control that were examined here

—body movement, attention towards reward, and verbal self-regulation finding that such strategies could be applied to various contexts, such as eating regulation. Though not the focus of this study, the role of inhibitory control strategies in relation to and as a tool for the management of childhood obesity may be crucial, especially with the link between children's BMI category and delay ability in this sample.

Although there were no differences in delay ability between boys and girls, it is important to note that 9 of the 11 children who ate the snack right away, and therefore did not have any codable data for inhibitory control strategies, were boys. Boys tended toward higher levels of motor activity as compared to girls, even after controlling for maternal, family, and other child characteristics, such as child BMI. There were no other sex differences in inhibitory control strategies used. Taken together, the findings on sex differences in motor activity levels and immediate reward seeking in this sample are consistent with prior studies on developmental maturation (Eaton & Yu, 1989) and the larger literature base on presentation and diagnosis of motor activity-related psychopathy, such as attention deficit hyperactivity disorder (ADHD) in childhood (i.e. (Rucklidge, 2010; Slobodin & Davidovitch, 2019)). Literature surrounding sex differences in underlying patterns of brain activation has revealed differentiation in neuro-attentional processes related to motor inhibition as well (Liu et al., 2013; Rubia et al., 2013; Spielberg et al., 2015).

Few studies have explicitly examined sex differences in motor control. Berlin et al. (2010) found that boys rated as having more conduct problems also had poorer response inhibition during a motor control focused task, Go/No-Go task, as compared to girls. However, after controlling for hyperactivity, there were no sex differences in response inhibition (Berlin & Bohlin, 2002). Interestingly, another study concluded that the combination of faster responses but lower accuracy, was associated with increased internalizing problems among girls, while faster responses alone (irrespective of accuracy), was shown to predict externalizing disorders among boys (Rosenberg-Kima & Sadeh, 2010). Motor behaviors may manifest in a sex-dependent manner and have associations with later behavioral and emotional expression, but this warrants further investigation.

Results of this study indicated generally no differences in children's delay ability by socioeconomic status, despite several other studies finding such differences (e.g., (Evans & English, 2002; Raver et al., 2011; Sturge-Apple et al., 2016). One unexpected finding, however, was that children from the lower social risk sample (*prenatal* sample) used higher levels of vocalizations than children from the higher social risk sample (*community* sample). Level of anticipation towards snack reward during the task did not differ by maternal, sample, and child characteristics. Maternal age was a consistent predictor of delay ability in most adjusted analyses executed here: children who were able to delay the full task time had older mothers as compared to children who did not delay the full task time. It is important to note that maternal age was only moderately correlated with maternal education in this analytic sample.

Some studies have examined the role of maternal age on children's self-regulatory capacity, indicating young motherhood as a risk factor for lower levels of child regulation development (Jusiene et al., 2015; Ng-Knight & Schoon, 2017). Despite advances in research on the role of early life adversity on children's self-regulation development (e.g., (Li et al., 2017)), the pathway by which maternal age relates to child self-regulatory development is unclear. Rather than looking at maternal age as a proxy for parenting/caregiving competency, younger motherhood may reflect a larger picture of unmeasured social risk relating contributing to early childhood adversity that is beyond the scope of this study. Although there were no differences in delay ability between the children in the *prenatal* and *community* samples in this study, mothers in the *community* sample were much younger than mothers in the *prenatal* sample. More insight is needed on how maternal age at different points in a child's developmental trajectory promotes or interferes with self-regulation development.

This work unities constructs from both the *dual influence* framework for inhibitory control and Yerkes-Dodson inverted-U relationship between arousal and performance (Duckworth & Steinberg, 2015; Yerkes & Dodson, 1908). In this study, volitional processes were operationalized through levels of motor activity and vocalizations over the course of the delay task. Impulsigenic processes were indexed using anticipatory behaviors towards the snack reward. Results from the current study extend upon prior findings (i.e., (Neuenschwander & Blair, 2017) by further examining the tug-of-war between processes underlying inhibitory control in early childhood.

The relationship between arousal/anticipation and delay performance can be conceptualized as Yerkes-Dodson inverted-U curve (Yerkes & Dodson, 1908) with both low and high levels of anticipation linking to worse delay ability, and moderate levels of anticipation as optimal for delay performance. From the current study, it is evident that children who have high anticipation but inadequate strategies to modulate arousal are not able to delay, such as children in the *Active* class. Children who have high anticipation but who are able to regulate themselves, such as children in the *Disruptive* class, or children who were moderately anticipating the reward (*Passive* class) were able to delay the most effectively. It is not just the level of impulses (anticipation) driving inhibitory control, but also the use of volitional strategies to modulate the pull of impulsigenic processes that facilitates inhibitory control. Thus, the key to training inhibitory control may be in meeting children's anticipation levels with effective strategies rather than focusing solely on reducing anticipation.

Much attention has been directed to understanding, describing, and training volitional processes underlying inhibitory control and self-regulation (Corriveau et al., 2016; Duckworth & Steinberg, 2015; Neuenschwander & Blair, 2017; Prinz, 2019). Less focus has been placed on impulsigenic processes underlying children's ability to wait. There is evidence that both impulsigenic and volitional processes contribute to socioemotional adjustment via elucidating pathways by which behavioral problems arise (Eisenberg et al., 2004; Lengua, 2002). Less adaptive self-regulation strategies have been linked to increased risk for internalizing and externalizing problems and adjustment issues (Supplee et al., 2011). Without establishing effective strategies, children may opt for less socially appropriate methods, for example aggression and outbursts, to deal with external stressors and emotions. Results here indicate that examining the balance of forces in children's inhibitory control can inform programs and interventions aimed at reducing impulsive behaviors.

The results have implications for interventions aimed at classroom behaviors. A key consideration for early childhood professionals is whether processes that help with school readiness can be bolstered through interventions. Gange and Nwadinobi (2018) reviewed self-control interventions implemented in preschool and elementary school aged children specifically targeting behavioral aspects of self-control and self-regulation through modifications of classroom curricula, behavior training, mindfulness, game/exercise based activities, and family-centered and longitudinal interventions (Gagne & Nwadinobi, 2018). Different types of interventions targeting cognitive, socioemotional, and/or integrated cognitive and socioemotional processes were distinguished. Specific to inhibitory control, Baker and colleagues (2019) found that targeted interventions in the early childhood ages demonstrated positive results across multiple domains such as school-related outcomes, socioemotional competence, and later mental health outcomes (Baker et al., 2019). Researchers suggest that inhibitory control itself is multi-dimensional and that disaggregating various components of inhibitory control, from a measurement perspective, may be difficult albeit necessary. The reviewed interventions did not explicitly distinguish between training volitional and impulsigenic components of self-regulation, elucidating a gap that this study starts to fill. Results from this study should be replicated in larger, more diverse samples to accurately draw conclusions, but nevertheless have implications for informing comprehensive intervention programs that target specific components of child self-regulation.

This study had several strengths and contributions to the field. Participating families had a broad range of data collected from well-established emotional and behavioral regulation tasks. Administering a battery of developmentally appropriate tasks to children provides a comprehensive assessment of psychological, cognitive, and behavioral domains of development. A major strength is that different facets of inhibitory control were studied by adapting and extending existing behavioral coding schemes to capture a more well-rounded picture of the mechanisms underlying children's self-regulation. The use of existing data and a well-recognized, standardized developmental task (Delay of Gratification/Marshmallow Test) to extract novel information on children's development is an important contribution to extend the wealth of prior work done using this task. The current study's methodology supports one of the strengths of observation-based data collection-- its potential for generating more information than originally intended, by reusing and extending existing data collected in innovative ways.

In addition, this study comprised of two separate groups of participants, a low risk (*prenatal*) sample and a higher risk (*community*) sample to include a more diverse sample than studies of this nature typically have. This enabled the examination of sociodemographic factors potentially contributing to differences in developmental trajectories. Limited research has been done on specific self-regulatory strategies developed and used in typically developing higher social risk children. Studies examining this have largely limited their samples to boys and/or children with diagnosed conduct-related disorders (Rodriguez et al., 1989; Supplee et al., 2011). In this study, the sample was expanded to encompass children from varying strata of potential social risk in early childhood. Finally, applying a person-centered approach to identifying patterns of inhibitory control differences is a strength of this study. This allowed for assessing differential contributions and patterns of underlying inhibitory control processes by using measured indicators to quantify multi-faceted developmental constructs.

It is important to also note the limitations. While this study included children from differing social risk strata, findings may still have limited generalizability. Replication of study methodology and analyses in a larger, more geographic and linguistically diverse sample would bolster study conclusions. The study methodology itself lends to such extensions with the use of a commonly known and widely collected developmental tasks and potentially relying on aggregating existing collected data alone for replication.

Despite the use of an extended coding scheme, there are a multitude of child behaviors that can be used to discern patterns of child inhibitory control that were not captured here. Future work would benefit from continuing to approach inhibitory control from both a top-down (i.e. using/adapting a validated behavior coding schemes) and bottom-up (i.e., observing spontaneous behaviors within the sample and then grouping them) approach. There may be limitations in observed data due to observation bias and data collection in a laboratory setting. Children may have acted differently in the laboratory setting or upon indication of being observed. Despite this, the protocol was designed to replicate developmentally appropriate real-world emotional challenges for children and RAs were trained not to regulate or bias children's reactions. Additionally, observers are likely to only see one snapshot of the child during the study visit, and therefore are unable to assess contextual and day-to-day fluctuations; this study is limited by only having one time point for observation/data collection.

Longitudinal studies to look at the interplay between volitional and impulsigenic processes over time are suggested. This would give insight to whether inhibitory control processes are stable or if they change over time. Children often face many transitions, physically, emotionally, socially, and structurally through the course of development. The focus here is on children who are 5 years old and transitioning into kindergarten environments. Future work should incorporate a range of developmental periods and a multi-level analysis of social, familial, and school/built environment-related factors that may contribute to differences in patterns of inhibitory control development and self-regulation.

4.6 Conclusions

The results here indicated that children whose inhibitory control strategies matched their level of anticipation were able to delay more successfully than children who were mostly driven by anticipation. It is important to recognize self-regulation as a balancing act between impulsive and voluntary processes. Though there have been advances in training children's voluntary processes, much less is known about impulsigenic processes and what to do to re-direct/weaken them. Strengthening measurement of distinct impulsigenic processes can help tailor interventions and maximize children's developmental potential. This study supports work done to recognize the importance of effectively measuring and targeting components of inhibitory control. Policy focus on narrowing achievement gaps in academic performance alone do not fully capture multi-level processes in early childhood development. Instead, practitioners and policy makers should strive to incorporate the complexity of early childhood developmental processes in their work.

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4.9 Tables and Figures for Manuscript 1

Table 4.1

Sociodemographic Characteristics comparing the Prenatal and the Community Sample

	Prenatal Sample (n = 54)	Community Sample (n = 90)	
Variable	Mean (SD)	Mean (SD)	t or X^2
Maternal Age (years)	37.4 (4.5)	29.9 (6.5)	8.0***
Maternal Education (years)	17.9 (2.9)	12.5 (2.1)	11.8***
Married (%)	94.4	16.7	82.3***
Maternal Race and Ethnicity (%)			
Non-Hispanic white	77.3	9.4	
Hispanic white	3.7	0	87.7***
Black	13.2	88.2	
Other	5.6	2.4	
Child Age (years)	5.3 (.29)	5.5 (.28)	-3.2**
Girls (%)	55	49	.60
Child Race and Ethnicity (%)			
Non-Hispanic white	71.7	6.9	
Hispanic white	5.7	2.4	80.7***
Black	16.9	90.6	
Other	5.6	0	
In Pre-K or Kindergarten (%)	67	68	.02

Note. * $p < .05$, ** $p < .01$, *** $p < .001$

Table 4.2

Bivariate Associations Between Confounders and Inhibitory Control Behaviors by Children's Delay Ability

	Delayed full time (n = 89)	Did not Delay (n = 44)	
Variable	Mean (SD)	Mean (SD)	t or X^2
Maternal Characteristics			
Maternal age (years)	33.8 (7.1)	31.0 (6.4)	-2.2*
Maternal education (years)	15.1 (3.6)	14.0 (3.6)	-1.6
Maternal Distress score	-.07 (.77)	.01 (.99)	.47
Child Characteristics			
Child age (years)	5.43 (.29)	5.5 (.28)	1.2
Female (%)	59.5	43.2	3.2
Obese and Overweight BMI (%)	27.8	45.5	4.0*
In Pre-K/Kindergarten (%)	70.8	59.1	1.8
Child PPVT score	101.8 (15.6)	97.6 (14.4)	-1.5
Sample			
Prenatal (%)	43.8	31.8	1.8
Community (%)	56.2	68.2	
Motor Activity	1.5 (.38)	1.8 (.61)	3.23**
Vocalizations	1.3 (.43)	1.4 (.54)	.48
Anticipation			
Low (%)	25.8	6.8	
Moderate (%)	42.7	18.2	22.7***
High (%)	31.5	75	

Note: n = 133 as 11 children did not delay for even one interval; * $p < .05$, ** $p < .01$, *** $p < .001$

Table 4.3

Fit Statistics for Inhibitory Control Latent Class Enumeration

Fit Statistic	1-Class	2-Class	3-Class
Log-likelihood	-358.6	-298.3	-272.2
AIC	729.3	618.5	576.3
BIC	746.6	650.3	622.6
SSA-BIC	727.6	615.5	571.9
Entropy	NA	1.00	.976
Lo-Mendell-Rubin (LMR) adjusted test	NA	115.9	50.1
LMR, *p*-value	NA	<.001***	.02*
BLRT test	NA	-358.6	-298.3
BLRT, *p*-value	NA	<.001***	<.001***

Note. * $p < .05$, ** $p < .01$, *** $p < .001$

Classification Probabilities for the Most Likely Latent Class Membership

	1-Class	2-Class	3-Class
Two-class model			
1. N = 72, 54.1%	1.00	1.00	
2. N = 61, 45.9%	.000	.000	
Three-class model			
1. N = 69, 51.2%	1.00	.000	.000
2. N = 53, 39.8%	.000	.999	.001
3. N = 11, 8.3%	.001	.120	.879

Table 4.4

Child Inhibitory Control Classes

Component	Class 1 (n = 69)	Class 2 (n = 53)	Class 3 (n = 11)
Motor Activity	1.4 (.04)	1.8 (.07)	2.1 (.16)
Vocalizations	1.2 (.03)	1.3 (.06)	2.5 (.14)
Anticipation (level)[a]	Moderate	High	High

Note. Mean (SE) reported unless otherwise noted. a. anticipation level based on probability and odds ratios of class membership.

Table 4.5

Results of Regression Analysis Examining Child Inhibitory Control Classes and Delay Ability

Variable	Odds Ratio	SE	Confidence Interval
Child Inhibitory Control Class			
1. Passive	REF	REF	REF
2. Active	.12***	.06	.05, .30
3. Disruptive	.28	.23	.06, 1.4
Maternal Age	1.1*	.04	1.0, 1.2
Maternal Education (years)	1.1	.10	.88, 1.3
Child Age	.79	.77	.16, 3.9
Child Sex	1.9	.90	.82, 4.8
Child BMI (overweight/obese vs. normal weight)	.42	.23	.15, 1.2
Sample (*prenatal* vs. *community*)	2.5	1.9	.53, 11.4
n	127		
LR Chi2 (8)	38.1***		

Note. $^*p < .05$, $^{**}p < .01$, $^{***}p < .001$, REF: reference is Inhibitory Control Class 1 (*Passive*: lower motor activity/vocalizations, and moderate anticipation)

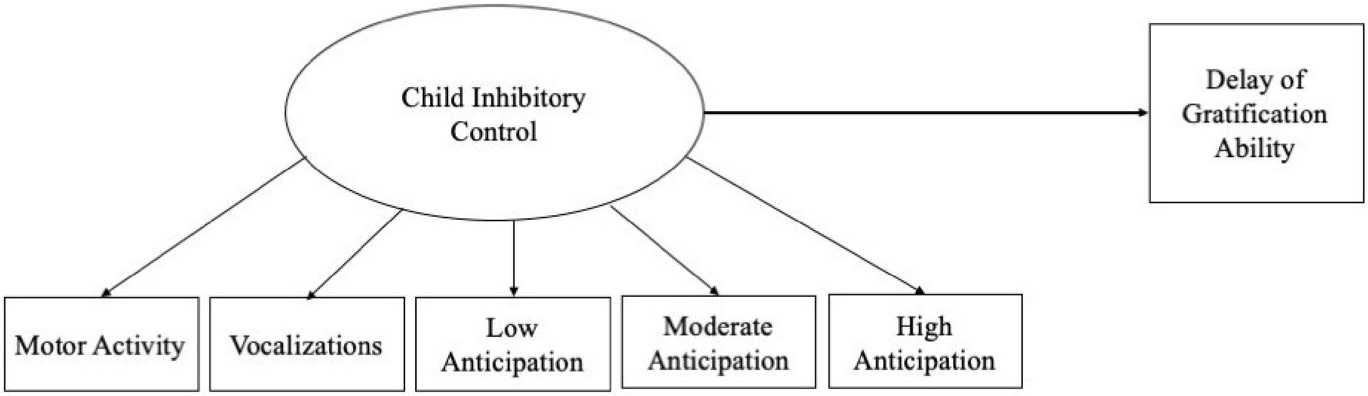

Figure 4.1

Latent Variable Diagram for Child Inhibitory Control

Note. The latent variable diagram shows measured indicators of inhibitory control (motor activity, vocalizations, anticipation) that were included for class enumeration. Motor activity and vocalizations were included as continuous indicators while anticipation was included as a categorical variable.

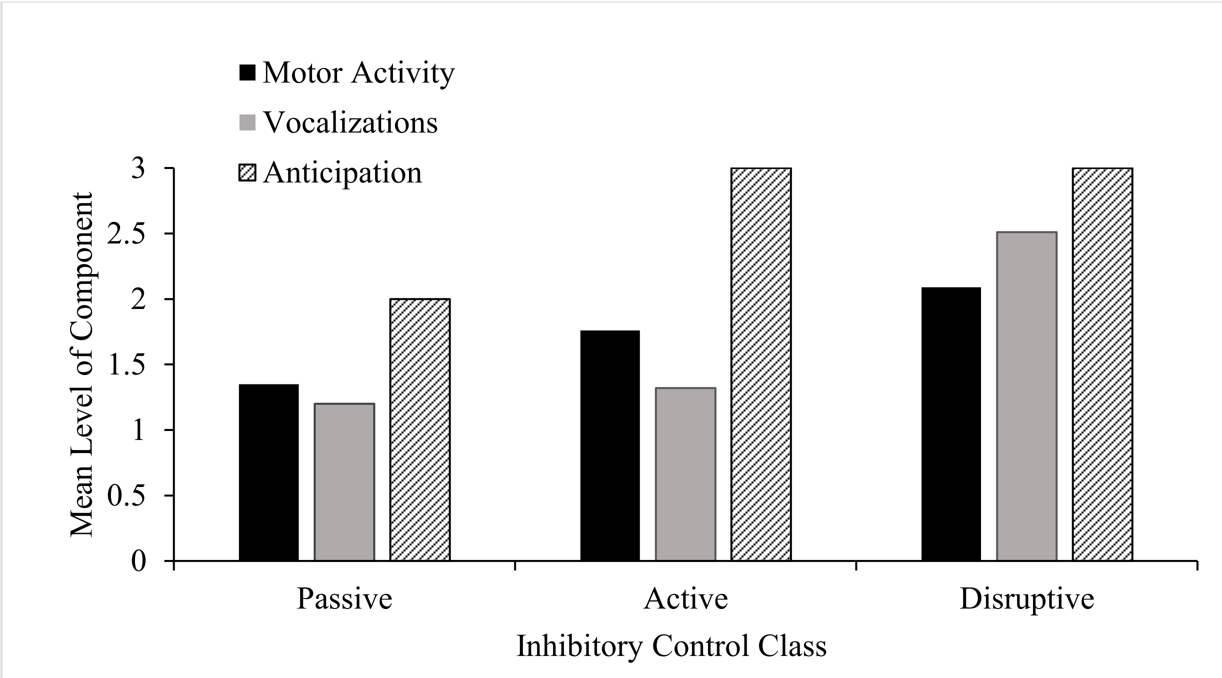

Figure 4.2

Composition of Child Inhibitory Control Classes

Note. Mean values for motor activity and vocalizations for each inhibitory control class are presented in this figure. Anticipation level presented here is based on odds ratios for class membership.

CHAPTER FIVE

Manuscript 2

More Than Meets the Eye: Examining Physiological and Behavioral Regulation during Delay of Gratification Task

5.1 Abstract

Children are faced with many situations where they must regulate impulsive responses in order to achieve a goal. Regulation comprises both behaviorally observable components as well as physiological regulation. Specifically, autonomic indicators, such as heart rate and RSA, are key components of self-regulatory capacity. This study focused on physiologic processes contributing to five-year old children's regulation by examining the concurrent role of heart rate and respiratory sinus arrhythmia (RSA) changes and inhibitory control strategies during a delay task in 126 children. Boys had lower pre-task RSA and were less likely to delay the full task time as compared to girls. Children who were obese/overweight were less likely to delay the full task time as compared to children who were underweight/normal weight. Changes in HR and RSA during task, or the difference between values at the end of the task as compared to the start of the task, were related to children's delay ability. Consistently, children who delayed showed less increase in HR and a decrease in RSA from the start of the task to the end of the task. Changes in HR and RSA during task were examined as moderators to the relationship between the three inhibitory control classes (*passive*: low motor and vocal regulation, moderate anticipation; *active*: moderate motor and vocal regulation, high anticipation; and *disruptive:* high on all indicators). Change in RSA during task moderated the relationship between inhibitory control classes and delay ability for children in the *active* class alone, aOR = .92, z = -3.1, p < .01. Results indicated that within the group of children who struggled to delay gratification based

on behaviorally observable indicators (*active* class), a subset of children who had appropriate autonomic regulation via vagal tone suppression, were able to delay successfully. Implications of findings with respect to autonomic regulation are discussed.

5.2 Introduction

Self-regulation plays an essential role in how children respond and react to stressful situations, indicative of children's emotional and behavioral adjustment. Delay of gratification, the ability to wait for a delayed reward instead of taking the immediate, lesser reward, is an index of inhibitory control and self-regulation often measured through structured delay of gratification laboratory assessments, such as the Delay of Gratification Task (Mischel et al., 1989). The ability to delay gratification comprises of a mixture of volitional (voluntary) and impulsigenic (driven by impulsivity) processes, manifesting externally through observable behaviors (i.e., fidgeting, self-talk) and internally though changes in physiological regulation (i.e., changes in heart rate) (Wilson et al., 2009). Distinguishing such processes may have implications for associations between children's delay ability and socioemotional adjustment.

Regulatory processes are linked to separate aspects of temperament such as negative emotionality and adjustment, and control-related characteristics such as impulsivity (Eisenberg et al., 2005). Temperament refers to consistent individual differences in reactivity and self-regulation that are physiologically based (Kiff et al., 2011). As such, regulatory processes have an impact on and are influenced by physiological regulation, specifically the autonomic nervous system. Examining physiological regulation in tandem with observable self-regulatory behaviors can help further identify bidirectional and dynamic psychophysiological associations implicated in children's emotional and behavioral development. The goal of this study, therefore, is to extend prior work by uniquely examining behavioral and physiological processes contributory to inhibitory control in early childhood.

Developmental researchers have continuously studied behaviorally observable self-regulatory strategies, starting as early as infancy. Strategies such as strategic attention deployment (i.e., directing attention towards or away from reward) (Rodriguez et al., 1989; Sethi et al., 2000), self-distraction (i.e., distraction or engaging in other activities) (Supplee et al., 2011), verbalizations (e.g., "I am not going to take the reward") (Manfra et al., 2014), and motor activity (i.e., fidgeting) have been examined as forms of arousal/anticipation control during inhibitory control tasks (Hong et al., 2017; Neuenschwander & Blair, 2017). For a detailed review see Manuscript 1 (Chapter 4). Very limited research has examined the spontaneous use of motor activity, vocalizations and anticipation in tandem, with little to no research on concurrent physiological regulation.

Autonomic Nervous System (ANS) and Psychophysiology

Reflecting regulatory processes through measurement of physiological indicators is critical to full understanding of the confluence of observable and unobservable components of child development and well-being. Examining the actions of targeted physiological systems as they change to psychological challenges or stressors allow for the integration of a multi-modal approach to developmental research (Fox et al., 2006). Psychophysiological measures are often used in developmental science to study emotional and attentional responses to stimuli to better understand cognitive processes underlying regulation and socioemotional development. (Cicchetti & Dawson, 2002; Fox et al., 2006; Porges et al., 2007; Utendale et al., 2014; van der Molen, 2000). Psychophysiological measures heave several benefits including the continuous nature of data collection, which allows for simultaneous analyses between physiological activity and behavioral/emotional effects during challenging stimuli. Additionally, psychophysiology can reveal more about internal regulation that is often difficult to capture via self-report or observations of overt emotional or behavioral states. Examining simultaneous behavioral and physiological states provides insight into concordance or discordance of intrinsic regulation processes and the external expression of such processes.

The autonomic nervous system (ANS) is commonly implicated in self-regulation and socioemotional capacity due to its interconnections with limbic brain systems responsible for emotional and psychological aspects of development (e.g., amygdala, thalamus, hypothalamus) (Mulkey & du Plessis, 2019). This complex interplay between ANS and the limbic neural network facilitates the way physical, environmental and social experiences shape behavior, emotion/self-regulation and socioemotional well-being through the course of development. Atypical ANS maturation and regulation has been linked to various maladaptive outcomes such as hyperactivity, aggressiveness, ADHD in childhood and increased risk of internalizing and externalizing behavior problems including, depression and mood disorders, into adulthood (Cicchetti & Dawson, 2002; Hinnant & El-Sheikh, 2009; Mulkey & du Plessis, 2019; van der Molen, 2000).

The ANS is responsible for maintaining physiological homeostasis through the parasympathetic (rest and digest) and sympathetic (fight or flight) branches; the parasympathetic and sympathetic branches work to regulate each other in the presence of perturbation. The input of a challenging stimulus is processed within the limbic components of the ANS, which signals sympathetic activation (i.e., increase in heart rate, blood pressure, muscle activity) and triggers a response to the stimulus (Laborde et al., 2017). Then, ideally, the parasympathetic branch applies a “vagal brake” to down-regulate physiologic responses in an attempt to return the body back to the pre-stimulus state once the stimulus is removed/irrelevant; the parasympathetic and sympathetic branches, therefore, dynamically interact to prepare, react, and adapt the body to changing environmental stimuli, or self-regulate (Fox et al., 2006).

Sympathetic and Parasympathetic Indicators of ANS regulation

A widely used and easily interpretable indicator of autonomic activation and regulation is heart rate (HR). Patterns of heart rate and variability are often evaluated before, during and after a challenge/stressor (Cicchetti & Dawson, 2002). Preliminary psychophysiological work exclusively relied on evaluating heart rate and changes in heart rate, though it was quickly noted that measuring heart rate alone was not a sufficient index of self-regulation, since changes in heart rate are not independent of factors such as motor activity and metabolic state, and therefore has both neural and non-neural influences (Cicchetti & Dawson, 2002; Fowles, 1980; Fox et al., 2006). Thus, researchers moved towards capturing variability in heart rate parameters and aimed to analyze several physiological indicators for evaluating adaptation and responses to environmental and psychological stimuli.

There are a number of ways to quantify variability in heart rate. One of these is respiratory sinus arrhythmia (RSA) (Berntson et al., 1993). RSA is defined as the naturally occurring variation in heart rate during the breathing cycle: inhalation is coupled with an increase in heart rate, while heart rate typically slows during exhalation, thus there is a cyclic rise and fall of heart rate that synchronized with breathing. RSA is often used as an index of vagal tone as there is a rhythmic fluctuation of parasympathetic influence with each breath when the ANS is balanced (Berntson et al., 1993). Collecting respiratory data in children is difficult, especially since respiration data is sensitive to movement or shifts in respiration belt placement. Therefore, investigators often rely on frequency-domain analyses (i.e. heartbeat to beat timing) for examining RSA in children. Individual differences in cardiac vagal regulation are often inferred from the magnitude of changes in RSA in response to challenges (Porges et al., 2007). In the absence of a challenging stimuli, vagal influence (vagal augmentation) slows heart rate, acting as a “brake”. However, in the presence of a challenge or stressful stimulus, vagal influence is suppressed (vagal suppression, “brake” is removed) to generate increased sympathetic activation and respond to the imminent perturbation (Hinnant & El-Sheikh, 2009). Vagal regulation (indexed through RSA), therefore is the reciprocal interaction between vagal augmentation and vagal suppression across changing environmental and psychological conditions. Although RSA has greater parasympathetic innervation than heart rate alone, changes in RSA can also be moderated by non-neural factors, such as levels of motor activity and self-soothing/regulatory behaviors (Porges et al., 2007).

ANS Regulation and Inhibitory Control

Empirical work examining associations between ANS (HR, RSA) parameters and children’s regulation provide supporting evidence of physiological antecedents of inhibitory control, such as adaptation to one’s environment (Sturge-Apple et al., 2016), sustaining attention (Skowron et al., 2014), employing effortful control (Taylor et al., 2015; Thayer et al., 2009) and relations with executive functioning (Laborde et al., 2017). Much of this literature focuses on associations between RSA and inhibitory control, as opposed to heart rate—in general, higher levels of basal RSA and increased vagal suppression (or a decrease in RSA relative to baseline or resting values) are moderately associated with better performance on multiple measures of self-regulation, including inhibitory control (Hinnant & El-Sheikh, 2009; Holochwost et al., 2018; Holzman & Bridgett, 2017). Individuals with lower basal RSA (indicative of higher arousal at rest), over suppression of RSA in response to challenge/stressor, or both may be highly attentive to environmental challenges to an extent that might be detrimental to appropriate coping (Hinnant & El-Sheikh, 2009). However, recent studies have indicated that the relationship between basal RSA/RSA regulation and self-regulatory capacity may be dependent on environmental context (i.e., socioeconomic status) (Sturge-Apple et al., 2016) and the nature of the challenge/task (i.e. executive function vs. emotion regulation) (Sulik et al., 2015).

Changes in HR to inhibitory control, specifically reward-related, tasks are thought to reflect activation of the behavioral activation system (BAS). BAS is a motivational approach system that activates responses to positive incentives and disengages in response to punishment (Wilson et al., 2009). Early work by Fowles (1980) points to empirical evidence linking patterns of heart rate with BAS, even when somatic activity, such as motor activity, is controlled for (Fowles, 1980). Numerous studies since then have examined patterns of heart rate with respect to self-regulation and socioemotional development since then (e.g.(Blair, 2003; Holzman & Bridgett, 2017; Mezzacappa et al., 1998; Ramirez et al., 2015; Wilson et al., 2009). HR responses during inhibitory control tasks differ based on level of children's impulsivity and activation of attentional processes, as HR reflects both parasympathetic regulation as well as sympathetic BAS activation (Holzman & Bridgett, 2017; Wilson et al., 2009). For example, HR decreases during an inhibitory control task (such as delaying gratification) might reflect an increase in attention towards reward (Suess et al., 1994), or emotional distress (Wilson et al., 2009), while increases in HR might reflect behavioral activation or shyness in some instances as well (Beauchaine, 2001). Existing findings on direction and magnitude of HR and inhibitory control are inconclusive and warrant further investigation.

Several child (i.e., sex, age, BMI) and demographic characteristics (i.e., socioeconomic status/maternal education) have been associated with HR/RSA regulation and inhibitory control in childhood (Cicchetti & Dawson, 2002; Giuliano et al., 2018; Hinnant & El-Sheikh, 2009; Holochwost et al., 2018), and were considered as potential covariates in the current study. Additionally, maternal distress was considered as a potential covariate in this study due to links between maternal distress and inhibitory control capacity—maternal responsiveness and degree of mother-child dyadic connectedness has been shown to predict better self-regulatory capacity (Holochwost et al., 2018; Kiff et al., 2011; Lengua et al., 2007)—and a growing body of literature on implications of maternal caregiving and sensitivity on children's stress response and reactivity, specifically ANS regulation (Bosquet Enlow et al., 2014).

ANS Regulation and Inhibitory Control Behaviors during Delay of Gratification

Inhibitory control capacity is often measured through tasks that challenge children's delay of gratification ability (Duckworth & Steinberg, 2015; Sethi et al., 2000), as is done in the current study. There is substantial heterogeneity in how and why children delay gratification, influenced by a mixture of intrinsic and extrinsic factors. Researchers have independently examined behavioral regulation (see Chapter 4) or physiological regulation (Skowron et al., 2014; Sturge-Apple et al., 2016; Sulik et al., 2015) during delay and inhibitory control tasks. Few studies have examined behavioral strategies in tandem with physiological regulation during delay of gratification tasks. Key studies that have informed the basis of the current study will be described in more detail next.

Although not explicitly testing inhibitory control, Kahle and colleagues (2018) examined links between multiple indicators of autonomic regulation and self-regulation behaviors in 83 preschoolers to index whether preschoolers' self-regulation behaviors were related to differences in physiology. Emotion regulation behaviors were assessed from videos during an anger induction task; children's self-soothing (i.e., sucking fingers or repetitive arm stroking), attention diversion (i.e., fixating gaze), and verbalizations (i.e., statements that reframed the goals or rules of the task, or celebratory statements) were coded during the task (Kahle et al., 2018). Autonomic indicators included RSA and pre-ejection period (PEP, measure of sympathetic activity) evaluated during the task (reactivity) and post-task (recovery). Verbalized regulatory strategies were linked with greater sympathetic reactivity and recovery while attention diversion strategies were linked with blunted patterns of sympathetic reactivity but increased sympathetic arousal post-challenge; in this study, RSA was not linked to regulatory behaviors (Kahle et al., 2018). Several other researchers have examined autonomic changes over a battery of self-regulatory tasks and concurrent behavioral and emotional regulation strategies (Calkins, 1997; Coulombe et al., 2019; Eisenberg et al., 2005) but few have parsed out these processes in delay-specific tasks.

Santucci and colleagues (2008) pooled data from two independent protocols conducted on separate days, but on the same sample of 54 children aged 4-7 years, to assess the role of vagal tone and emotional regulation strategies both specifically during delay of gratification tasks. About half of the children included in this study had mothers with childhood-onset depression, the other half was considered the control group (children with mothers who have never been diagnosed with depression). Emotion regulation strategies such as active distraction (i.e, shifting attention away from delay object, singing or dancing), focus on delay object (i.e., talking about, looking at or touching reward), passive waiting (i.e., standing or sitting quietly without engaging with test materials), information gathering (i.e., asking questions about the waiting situation, but not asking about changing the situation), and physical comfort seeking (i.e., asking to be held) were coded during the delay task (Santucci et al., 2008). These emotion regulation strategies were combined into three constructs (negative focus on delay, behavioral distraction, and positive reward anticipation) for further investigation with physiological measures and child temperament (assessed via maternal report). Cardiac vagal tone (RSA) at rest (baseline), during delay task (reactivity), and post-task (recovery) were examined with respect to emotion regulation strategies. Lower vagal recovery and higher mother-reported negative affect were associated with maladaptive emotional regulation strategies (negative focus on delay) and failure to delay (Santucci et al., 2008). Vagal tone measures and temperament were not associated with adaptive emotion regulation strategies (behavioral distraction or positive reward anticipation) and maternal depression status was unrelated to any findings.

Children's physiological responses (i.e., heart rate and electrodermal reactivity) during a delay task were examined with respect to self-regulation and emotional and behavioral adjustment in 91 children aged 8-11 years (Wilson et al., 2009). Incorporation of electrodermal reactivity provides a marker of sympathetic reactivity for construction of physiological profiles of *only* children who successfully delayed in concordance with ratings of observable difficulties with waiting during the task. Ratings of behaviors indicating difficulty delaying included observations such as boredom, fidgeting, annoyance, facial grimaces and focusing on the prize during the delay task. These behaviors generated an overall difficulty waiting score based on intensity and frequency of behaviors (i.e. mild difficulty waiting = 1 to 5 observed behaviors of low intensity). In addition to ratings of behavioral observations during the delay task, Wilson et al. (2009) also examined emotionality, self-regulation and child adjustment problems using maternal and child self-reported questionnaires. Cluster analysis revealed three profiles for children who delayed the full task time: 1) children who waited easily with low electrodermal and moderate heart rate reactivity 2) children who had difficulty waiting with high electrodermal and moderate heart rate reactivity, and 3) children who had difficulty waiting with low electrodermal and low heart rate reactivity (Wilson et al., 2009). These groups were examined with respect to negative emotionality, self-regulation and adjustment problems, indicating that children with low electrodermal and low heart rate reactivity had the lowest self-regulation and highest adjustment problems, similar to children who did not delay the full task time. It is important to note that cluster analysis was only limited to children who delayed the full task time, therefore not tapping into physiological and behavioral processes underlying lapses in inhibitory control.

Current Study

Despite substantial research examining ANS and self-regulation, little is known about whether HR and RSA relate differently to volitional and impulsigenic processes underlying inhibitory control (Sulik et al., 2015). A person-centered (latent variable) approach may be advantageous to capture such heterogeneity and elucidate the extent to which children with differing levels of volitional and impulsigenic capacities struggle within the delay context, and whether physiological regulation buffers or facilitates lapses in delay ability. Relations between inhibitory control strategies and delay ability have already been examined in this sample (Manuscript 1, Chapter 4). Therefore, this study examines the role of psychophysiological regulation and reactivity (HR, RSA) in children's delay ability by: 1) comparing attributes of children who delayed versus did not delay through measures of autonomic reactivity, changes in HR and RSA during task, and patterns of physiologic indicators during the delay of gratification task; 2) exploring sociodemographic correlates of the autonomic indicators in children who delayed and did not delay the full task time; and 3) examining the moderating role of autonomic indicators on the relationship between latent inhibitory control classes and delay ability.

5.3 Methods

Participants

Participants include 5 year old children who originally participated in a study that commenced during the prenatal period (the *prenatal sample*) and an additional group of children from the same geographic vicinity but representing a less affluent population living in a large urban center (the *community sample*) (Riis et al., 2015). Description of sampling procedures and eligibility for this study was included in Chapters 3 and 4.

Of the 151 children who participated in a laboratory visit, 54 from the *prenatal* sample and 90 from the *community* sample had recorded and useable delay of gratification task (n = 3 had incomplete visits or did not complete delay of gratification task (all in *community sample), n* = 4 with no video data (all in *prenatal sample*)). Eleven children (9 boys) ate the snack reward immediately upon presentation and, therefore, did not have audio/video recorded data to code, resulting in 133 children with usable inhibitory control strategy (behavioral) data. Of the 133 children, 7 children did not have usable physiological data due to electrocardiograph (ECG) pads becoming unstuck (n = 6) or high levels of artifact (n = 1). Therefore, the final analytic sample was restricted to 126 children (n = 50 *prenatal* sample and n = 76 *community* sample) with usable physiological and behavioral data.

Sample Characteristics

Table 5.1 describes and compares sociodemographic characteristics for 126 mother-child dyads in the *prenatal* and *community* samples. Women in the *prenatal* sample were on average older, completed more years of education and were more likely to be married than women in the *community* sample. Women in the *community* sample were more likely to be Black; women in the *prenatal* sample were predominantly non-Hispanic white. Children in the *community* sample were slightly older than children in the *prenatal* sample, with no differences in child sex or school attendance between the samples (Table 5.1). Children's reported race and ethnicity matched mothers' race and ethnicity composition for each sample.

Procedures and Measures

Study visits were conducted in a dedicated laboratory space. Visits lasted approximately 90 minutes during which children engaged in a battery of tasks to assess cognitive and executive functioning and emotional regulation. ECG data were collected throughout the study visits on children, yielding measures of heart rate and respiratory sinus arrhythmia (RSA). All tasks were audio/video recorded. At the same time, mothers completed questionnaires on themselves and their child's behavior and development in a separate room.

Delay of Gratification Task and Inhibitory Control Strategies

The Delay of Gratification Task (delay task) is an assessment of self-control, manifested as impulsivity regulation, and inhibitory/attentional controls (Mischel et al., 1989; Murray et al., 2016; Neuenschwander & Blair, 2017). It is a developmentally appropriate method to assess inhibitory control and has been used to empirically evaluate behavioral and emotional regulation in young children (Mischel et al., 1989; Watts et al., 2018). Details of this task are described in Chapters 3 and 4. Children were given the option to take an immediate reward of one snack (either marshmallow or pretzel based on child's preference) or wait for eight minutes for two snacks. The current analyses examined data from the instruction period (instruction duration was defined as the period of the time when the research assistant provided task instructions to the child) and task period (task duration was either 8 minutes or until the child ate the snack reward/rang the bell to bring the research assistant back). Delay ability (wait vs. no wait) had been previously coded for this lab task.

Additional codes surrounding motor activity and vocalization self-regulatory strategies, and anticipation towards snack reward were introduced to assess individual differences that contributed to ease or difficulty in delaying (see Chapter 4 and Appendix A for details). Continuous composite scores for motor activity and vocalizations, created by averaging level of motor and vocal self-regulation strategies through the delay period (up to 8 minutes, or 16 intervals of 30 seconds) separately, and a global categorical score for anticipation during the delay task were used as indicators to fit an unconditional latent model to characterize inhibitory control classes. Details on class enumeration and evaluation are in Chapter 4. Three distinct inhibitory control classes were derived: *Passive* (low motor, low vocal, moderate anticipation), *Active* (moderate motor, moderate vocal, high anticipation) and *Disruptive* (high motor, high vocal, high anticipation). These latent classes of inhibitory control will be used to examine the joint role of behavior and physiology in predicting delay ability.

Psychophysiological Data Acquisition

Participating children were seated in a chair during the study visit and heart rate acquisition. Three electrodes were placed on each child: the first electrode was placed on the right clavicle near the sternum, superior to the first rib; the second electrode was placed near the junction of the transpyloric and midclavicular planes; and finally, the third electrode was placed on the upper abdomen near the lower right rib. ECG data were sampled at 1000 Hz and recorded continuously for the duration of the laboratory visit Mindware Technologies, LTD (Columbus, OH) BioNex Desktop Platform.

Data were subsequently analyzed using Mindware Technologies, LTD (Columbus, OH) Heart Rate Variability (HRV) Analysis Software version 3.0. Artifact was detected using dual algorithms (IBI Min/Max and MAD/MED) within Mindware. The IBI Min/Max algorithm flags inter-beat-intervals (IBIs) that fall above or below the specified maximum (200 beats per minute (bpm)) and minimum (40 bpm) thresholds. The MAD/MED algorithm examines the variability of IBIs and flags outliers as potential artifact (see (Berntson et al., 1990) for further details). R-waves that were identified as potential outliers were marked. ECG data were manually edited based on flagged artifact by deleting erroneous R-waves, adding missing R-waves, and estimating where R-waves should be if data were not clear. Data editing was required for 25 cases due to physiological artifact, outliers/implausible physiologic values, or missing data within Mindware Software.

ECG data were visually inspected for each child during the delay of gratification segment of laboratory visit and segments with more than 5% estimated R-waves were dropped. Sensitivity analyses were performed comparing values from the 25 cases with edited data and treating any outliers/missing values as missing, resulting in no differences in means. In one case (*community* sample), physiological data was collected but not usable due to high levels of artifact and R-wave estimation; resulting in the final analytic sample size of 126 children.

Psychophysiological Data Quantification

Analyses here are performed on digitally derived R-waves from the ECG using Mindware Technologies, LTD (Columbus, OH) Heart Rate Variability (HRV) Analysis Software Version 3.2.3. Data were extracted and aggregated into an analyzable database with a focus on the following measures of heart rate and variability during the instruction period (total) and task period (total and 30 second intervals, up to 16 intervals depending on wait time). ***Heart Rate (HR):*** Inter-beat-intervals were timed (msec) and converted to heart rate (bpm, beats per minute). Mean values were computed for the duration of the instruction period, for the total task period and in 30 second intervals during the task. ***Respiratory Sinus Arrhythmia (RSA):***

Respiration was not measured directly so RSA was calculated based on IBI time series and spectral analysis using high frequency heart rate variability as follows: RSA= ln (HFPower). RSA was calculated using age-adjusted respiratory frequency bands, 0.15-0.8 Hz, as typically done to account for children's faster rates of breathing (Bar-Haim et al., 2000). Mean values were computed for the length of the instruction period, for the total task period and in 30-second intervals during the task.

Two sets of change scores were computed to assess physiological regulation and reactivity:

HR and RSA Reactivity (dMeanHR, dMeanRSA): the differences between mean values during the instruction period and overall task period for HR and RSA separately to assess change in autonomic functioning pre-challenge (instruction period) and during the challenge (task); mean task HR and RSA values were subtracted from mean instruction HR and RSA, therefore positive values indicate increase in HR or RSA in the task period as compared to instruction period.

Change in HR and RSA during Task (dDelayHR, dDelayRSA): to characterize changes in HR and RSA during the task period, difference scores were calculated for each child by subtracting mean HR or mean RSA value at the end of the task (i.e. either 16th interval or when the child rang the bell to end the task) from the mean values at the start of the task (interval 1). For example, if a child waited the full task time, the delta for HR or RSA was calculated as mean physiological value at interval 16 minus the mean physiological value at interval 1; if a child only waited part of the time, the delta reflected the mean physiological value of the last 30-second interval the child waited minus the mean value at interval 1. This approach was taken to account for the varying number of intervals a child waited. Positive values for this variable indicate lower starting HR or RSA value compared to values at respective end of delay task (increasing HR or RSA during task period).

The instruction period was relatively brief (M = 82.0 seconds, SD = 22.9) compared to the task period (M = 367.9 seconds, SD = 175.1). However, mean HR in the instruction period and task period were highly correlated, r (124) = .82, p < .001, as were mean RSA during instruction and task period, r (122) = .76, p < .001, indicative of the robustness of these measures. Since the task period for some children was as short as 30 seconds, correlations were recalculated using data from a subset of children who had at least 3 minutes of task data to assess the stability of the derived RSA and HR measures. The correlation between mean HR and mean RSA for children with at least 3 minutes of task data, r (95) = -.55 p < .001, was similar to the correlation with all children, r(124) = -.51, p < .001, providing confidence in the reliability of the measure regardless of wait time.

Maternal and Child Covariates

Maternal age, education, marital status, race and ethnicity, and child age, sex, race, ethnicity and school status were all collected through maternal report. As the delay task specifically uses a snack as a reward, child body mass index (BMI) was assessed as a confounder. Child height and weight measured at the study visit was used to compute age and sex-adjusted BMI and derive categorical weight status (underweight/healthy vs. overweight/obese) based on the Center for Disease Control guidelines for age and sex-adjusted BMI percentile cut-offs (*Healthy Weight: About Child & Teen BMI.*, 2018).

Child Receptive Language. Children's Peabody Picture Vocabulary Test (PPVT) was administered during the lab visit. The PPVT was used to measure receptive language as a proxy for verbal intelligence (see (Protzko, 2015). The delay task relies on children's abilities to comprehend and follow the rules presented to them. Therefore, to account for children's verbal intelligence PPVT scores (standardized *within* the sample) were examined as a potential confounder.

Maternal Psychological Distress. A maternal distress factor score that had been previously derived using the State-Trait Anxiety Inventory (STAI) (Spielberger, Gorsuch, & Lushene, 1968), Center for Epidemiological Studies- Depression (CES-D) (Radloff, 1977), and Parenting Stress Index, Fourth Edition Short Form (PSI-SF) (Abidin, 2012) was used in the analyses; for details on factor analysis see (Riis et al., 2016). Higher scores for this variable indicated higher levels of maternal distress.

Data Analyses

Descriptive and exploratory analyses (t-tests, χ^2 analyses, and Pearson correlation coefficients) were utilized to examine differences in selected maternal and child covariates, and instruction duration between children who delayed the full time versus children who did not delay the full time for the sample of children who had physiological data. Potential confounders such as maternal age, maternal education, child age, and child BMI were retained in all analyses. In addition, a variable indicating whether children were from the *prenatal* or *community* sample (sample indicator) was included to account for potential unmeasured/non-measurable differences in samples, and to address the substantive differences in sample characteristics. For the remaining potential covariates (instruction duration, maternal psychological distress, child PPVT score), only those that reached a cutoff of $p < .10$ were retained. Variance inflation factors (VIF) were assessed for potential multicollinearity between sample indicator and selected maternal demographics (maternal age and maternal education).

The main independent measures were HR and RSA during the instruction and task segments and HR and RSA change scores from instruction to task (dMeanHR or dMeanRSA) and from start of task to end of task (dDelayHR or dDelayRSA). Exploratory and bivariate analyses (i.e., histograms, box-plots, t-tests, χ^2 tests and Pearson correlation coefficients) were used to examine distribution of these measures and sociodemographic correlates. Bivariate analyses (t-tests, Mann-Whitney two-sample statistics) were used to test associations between physiological variables and delay ability. Plots of mean HR and RSA during the delay task were generated to examine epoch by epoch patterns (Figures 5.1 and 5.2). Differences in these HR and RSA patterns between children who delayed and did not delay were examined using two sample t-tests, Mann-Whitney two-sample tests and variance ratio tests. Mixed effects models, with and without a time by delay interaction term, were considered to further quantify patterns in HR and RSA. Bivariate analyses and examination of epoch by epoch mean plots were used to inform which independent variable(s) best characterized physiological reactivity for the delay task. The adjusted relationship between selected physiological measures and delay ability was investigated using separate multivariate logistic regression models, with covariates added in a stepwise manner. Models were evaluated for fit using model fit statistics and diagnostics (i.e., χ^2 goodness of fit, Akaike Information Criterion (AIC), Bayesian information Criterion (BIC)).

To examine the joint association between physiological measures and inhibitory control classes in predicting delay ability a 3-step approach to mixture modeling was employed. First, the heterogeneity of inhibitory control strategies children used during the delay task was modeled using latent class analysis (measurement model, see Chapter 4). Second, an unconditional model was run to create BCH weights that reflect measurement error of the latent class variable; using a weighted multiple-group model avoids class shifting in subsequent models

(Asparouhov & Muthén, 2014). Third, using the BCH weights, the moderating role of physiological variables on the relationship between latent inhibitory control classes (independent variable) and delay ability (dependent variable) was tested. The third step (structural model) modeled the influence of covariates on the latent inhibitory control (IC) classes and outcome of interest (main effect) as well as interactions between latent IC classes and physiological variables (moderation). Full information maximum likelihood estimation was used to account for missingness.

Analyses were conducted using Stata version 16.1 (StataCorp, 2019) and *Mplus* version 8 (Muthén & Muthén, 1998-2017).

5.4 Results

Sociodemographic Correlates of Delay Ability

Of the 126 children with usable physiology and behavioral data, 82 (65%) delayed the full task time and 44 did not. Children who delayed the full task time were more likely to be girls ($\chi2(1) = 4.2$, $p < .05$) and more likely to be underweight/normal weight than overweight/obese ($\chi2\ (1) = 4.5$, $p < .05$) as compared to children who did not delay. Post-hoc analyses were conducted to examine if boys and girls had differing delay ability by sample, revealing that boys in the *community* sample were less likely to delay the full task time as compared to girls in the *community* sample. There were no differences between boys' and girls' delay ability in the *prenatal* sample. Child age was unrelated to delay ability. Delay ability was not distinguished by school attendance or PPVT score with neither variable reaching the set cut point of $p < .10$, and thus were not included as covariates in analyses.

There was no difference in delay ability by sample (*prenatal* vs. *community*) although mothers of children who delayed were somewhat older than mothers of children who did not (*M*

= 34.1, *SD* = 7.2 vs. *M* = 31.0, *SD* = 6.4; $t(124) = -2.35$, $p < .05$). There were no other differences detected in maternal characteristics or maternal distress when comparing children who did and did not delay the full task time. Nonetheless, a sample indicator was retained to account for unmeasured/non-measurable confounding due to differences in sample composition (see Table 5.1).

There was a trend level association between delay ability and the duration of the instruction period, such that children who delayed the full task time had slightly shorter instruction periods than children who did not (*M* = 78.9 seconds, *SD* = 19.1 vs. *M* = 87.6 seconds, *SD* = 28.1; $t(64.8) = 1.8$, $p = .07$); variance in instruction duration for children who delayed and did not delay significantly different, therefore two-sample t-test accounting for unequal variances was used. Instruction duration, therefore, was considered as a covariate and examined with selected physiological measures for confounding. Examining variance inflation factors (VIF) showed that maternal age, maternal education and sample indicator were not collinear in this analytic sample (mean VIF = 1.22), and therefore all three covariates were considered in subsequent analyses.

Sociodemographic Correlates of Cardiac Variables

Segment and change scores for HR and RSA did not differ between the *prenatal* and the *community* samples: instruction HR *M (SD)* = 94.6 (9.1) vs. *M (SD)* = 93.7 (8.9); task HR *M (SD)* = 96.9 (9.4) vs. *M (SD)* = 94.3 (9.5); dMeanHR *M (SD)* = 2.4 (6.7) vs. *M (SD)* = 2.4 (6.7); dDelayHR *M (SD)* = 16.8 (33.7) vs. *M (SD)* = 11.5 (26.3); instruction RSA *M (SD)* = 6.9 (1.9) vs. *M (SD)* = 6.8 (1.3); task RSA *M (SD)* = 7.1(1.6) vs. *M (SD)* = 7.0 (1.3); dMeanRSA *M (SD)* = .004 (1.4) vs. *M (SD)* = .14 (.70) (unequal variances); and dDelayRSA *M (SD)* = .70 (2.6) vs. *M (SD)*= .23 (2.7), respectively, all *p*s > .22.

There was a trend level association between child BMI category and HR during instruction period only, such that children who were overweight/obese had a faster average HR of ~3 bpm than children who were underweight/normal weight, $t(124) = -1.2$, $p = .06$. No other associations were detected with child covariates (child age and child sex) and the cardiac segment values or change scores. Child sex was associated with mean instruction RSA, such that boys had lower average RSA during the instruction period as compared to girls ($M = 6.6$, $SD = 1.5$ for boys vs. $M = 7.2$, $SD = 1.6$ for girls, $t(122) = -2.3$, $p < .05$). There were no other associations found between child-level covariates and RSA parameters. None of the selected maternal covariates (maternal age, maternal education, maternal distress) were related to the cardiac segment values or change scores.

Cardiac Variables and Delay Ability

Differences in the segment values and change scores comparing children who delayed the full task time and children who did not are presented in Table 5.2. No differences in mean HR or RSA values during instruction or task, or for dMeanHR and dMeanRSA comparing children who delayed to children who did not delay were detected. There were only differences in dDelayHR and dDelayRSA; children who delayed showed less increase in HR from the start of the task to the end of the task ($M = 4.7$ bpm, $SD = 6.6$ vs. $M = 30.3$ bpm, $SD = 44.8$, $t(44) = 3.8$, $p < .001$) and a greater decrease in RSA ($M = -.35$, SD = 1.5 vs. $M = 1.8$, $SD = 3.6$, $t(51.3) = 3.8$, $p < .001$) from the start of the task to the end of the task as compared to children who did not delay.

Epoch by epoch means of HR (Figure 5.1) and RSA (Figure 5.2) for children who delayed and children who did not delay were plotted to discern whether children exhibited different temporal patterns of HR or RSA during the task period. Visual examination suggested that children who delayed had stable but somewhat increasing HR during the task, while children who did not delay showed accelerating HR commencing near interval 6 (3 minutes into the task) diverging from delayers. However, point by point comparisons of mean HRs, using t-tests, did not indicate significant differences between children who delayed and did not delay. Differences were likely not detected due to small sample sizes in the group of children who did not delay and the somewhat larger variances when comparing delayers to non-delayers. Children who delayed had a more stable but decreasing trend in RSA during the task period, while non-delayers showed greater variation in epoch by epoch means. Again, point by point comparison of mean RSAs did not indicate significant differences between children who did and did not delay.

Mixed effects regression models were run to further examine patterns of HR and RSA during the task. Separate models for HR and RSA were run with a random intercept at the subject level, to account for expected associations in HR and RSA values within subject. Mixed effects models with a time by delay interaction term were considered and model fit was compared to models without the interaction term. For HR and RSA, likelihood ratio tests indicated that the model with interaction term fit better than the model without the interaction term (for HR model $LR\ \chi2(29) = 98.2$, $p < .001$; for RSA model $LR\ \chi2(29) = 46.1$, $p < .05$). Results of the models indicated no significant difference in patterns of HR (*coeff* = -1.63, $z = -.86$, $p = .40$) or RSA (*coeff* = .14, $z = .44$, $p = .66$) between delayers and non-delayers. The sample size is small and so power to detect interaction effect is limited in these models. These models were considered only for exploratory purposes.

Based on analyses between segment values/change scores and delay ability, while taking into consideration the patterns of HR and RSA during the delay task, only dDelayHR and dDelayRSA were used in multivariate analyses, controlling for maternal and child covariates. Covariates that were retained for these analyses are maternal age, maternal education, child age, child sex, child BMI category, sample (*prenatal* vs. *community)*, and instruction duration. Fit statistics, including AIC and BIC, were examined as covariates were added in a step-wise manner. Models were also evaluated using goodness-of-fit tests to assess whether the observed sample data was representative of associations that one would expect at the population level. Fit statistics indicated that multivariate models accounting for all selected covariates were appropriate for the data. The direction of associations between dDelayHR and delay ability (a*OR* = 0.96 (CI: .94, .99), z = -3.1, p < .01) and dDelayRSA and delay ability, a*OR* = .70 (CI: .57, .87), z = -3.2, p = .001, remained after adjusting for covariates. None of the covariates in these models reached statistical significance.

Inhibitory Control Classes and Delay Ability: Moderating Role of HR and RSA Reactivity

Preliminary analyses (ANOVA) were used to look at unadjusted differences in HR and RSA reactivity among the previously derived latent classes of inhibitory control (*Passive*, n = 64; *Active*, n = 52; *Disruptive* = 10). The relationship between delay ability and IC classes was examined in Manuscript 1 (Chapter 4). To review, children in the *Active* class had lower adjusted odds of delaying full task time as compared to children in the *Passive* and *Disruptive* classes (Manuscript 1, Table 4.5). Class sizes slightly differ from Manuscript 1 (Chapter 4) due to a smaller analytic sample here based on availability of intact physiological data. Analyses indicated differences in dDelayHR and dDelayRSA changes among the latent inhibitory control (IC) classes, $F(2, 123) = 8.2$, p < .001 and $F(2, 123) = 6.0$, p < .01 respectively. Although only variables measuring changes in HR and RSA during task (dDelayHR and dDelayRSA) were selected based on associations with delay ability, analysis of variance was conducted to examine whether any of the other HR and RSA variables related to IC classes. There were no other significant associations, so moderation analyses were limited to examining dDelayHR and dDelayRSA.

To examine the moderating role of HR and RSA reactivity on the relationship between IC classes and delay ability, a 3-step approach was used. HR reactivity and RSA reactivity variables were centered at their respective means to test for moderation and to enhance interpretability. Covariates were held constant across classes. Final estimates presented here were obtained from the structural model that accounted for the influence of covariates on class membership and delay ability. Results from the main effects model indicated no relationship among dDelayHR (*est.* = -.003, a*OR* = 1.00, $p = .12$), dDelayRSA (*est.* = -.02, a*OR* = .98, $p = .38$) and delay ability, after controlling for selected covariates and IC class. Despite non-significant main effects, moderation was still tested to examine the heterogeneity seen in preliminary results of this study.

Three models for testing moderation effects were run with IC class as the independent variable, dDelayHR and/or dDelayRSA as the moderator and delay ability as the outcome (dDelayHR (Model 1), dDelayRSA (Model 2), joint moderating role of dDelayHR and dDelayRSA change (Model 3)). Wald test indicated significant interaction effects in all three models (Model 1: *Wald* (2) = 7.4, $p < .05$; Model 2: *Wald* (2) = 25.3, $p < .001$; Model 3: *Wald* (2) = 9.3, $p < .01$).

Children in the *Active* class were less likely to delay the full task time if they had a greater dDelayHR, a*OR* = .99, $z = -2.6$, $p < .01$; children in the *Active* class were less likely to delay if their HR was higher at the end of task as compared to the start of task. No other significant associations with covariates or interactions with IC classes were detected in Model 1. Similarly, children in the *Active* class were less likely to delay the full task time if they had a dDelayRSA change, aOR = .94, z = -3.8, p < .001; children in the *Active* class were less likely to delay if their RSA was higher at the end of task as compared to the start of task. However, in Model 2, children's BMI was significantly associated with delay ability, after controlling for maternal, child, sample, physiological and IC class variables, aOR = .84, z = -1.9, p = .05. Here, children who were overweight/obese were less likely to delay full task time as compared to children who were underweight/normal weight. Results of Model 3 are presented in Table 5.3 and represented in Figure 5.3. When the moderating role of dDelayHR and dDelayRSA were examined together, dDelayRSA played a significant role in predicting delay ability; children in the *Active* class again were less likely to delay if they had a greater dDelayRSA, aOR = .92, z = -3.1, p < .01 (see Figure 5.3). Similar to Model 2, children who were overweight/obese were less likely to delay the full task time compared to children who were underweight/normal weight, aOR = .82, z = -2.3, p < .05. No other covariates were significant in Models 2 and 3.

5.5 Discussion

The main objectives for this study were to examine whether physiological differences were related to children's delay ability and how they contributed to the relationship between inhibitory control strategies and delay ability in 5-year-old children. Autonomic indicators allowed for the identification of distinct unobservable processes underlying observable inhibitory control strategies in response to a delay task. The current study findings reveal that: 1) child sex and child BMI both related to autonomic measures and children's delay ability; 2) changes in heart rate and RSA during the delay task were associated with children's delay ability; and 3) changes in RSA during the delay task moderated the relationship between children's use of inhibitory control strategies and children's delay ability for children who had high levels of anticipation but not the matching level of self-regulatory strategies to quell their anticipation (*active* class).

In this sample, girls were more likely to delay the full task time as compared to boys. Post-hoc analyses showed that boys in the *community* sample were less likely to delay as compared to girls in the *community* sample while no sex differences in delay ability were detected in the *prenatal* sample. This is compounded by the observation that 9 out of 11 children who did not wait for a single 30-second interval, and therefore not included in the analyses, were boys. There has been considerable research examining sex differences in self-regulatory capacity, including delaying gratification (Doidge et al., 2018; Hosseini-Kamkar & Morton, 2014; Silverman, 2003). Studies on delayed of gratification tasks have reported mixed findings on sex differences in typically developing children. Some research has suggested that girls tend to delay gratification longer than boys (Silverman, 2003) while other studies have found no sex differences in delay ability alone (Doidge et al., 2018) citing various developmental and evolutionary reasons. The sex differences in delay ability seen in the *community* sample alone suggest a potential sex by sample interaction to be considered to extend this work. In the current study, girls also had higher RSA values during the instruction period than boys, suggesting activation of a vagal "brake"—slowing down heart rate to maintain physiologic homeostasis in the absence of threats or challenges. One possibility for the sex differences seen here is due to the low pre-task RSA boys had contributing to lesser self-regulation capacity to delay gratification. The low pre-task RSA seen in boys could also be an indication of higher anticipation towards the snack reward while instructions are being presented, therefore contributing to failed delay of gratification.

Children who were overweight or obese were less likely to delay the full task time as compared to children whose BMI was categorized as underweight or normal weight. This relationship remained even after adjusting for maternal, child, sociodemographic, inhibitory control strategies and the moderating role of autonomic indicators. About 35% of children in this study were categorized as overweight or obese based on sex and age-adjusted BMI percentiles. Typically, food-related rewards are used in delay of gratification assessments. This finding is consistent with that of a systematic review on childhood obesity and delay of gratification behavior revealed that all studies using a food-based reward in children found a clear relationship between inability to delay gratification and overweight/obese status (Caleza et al., 2016). Several studies included in Caleza and colleagues' review examined relationships between children's BMI and delay ability using both food and non-food rewards. In general, these studies found that obese and non-obese children did not differ in delay ability when the reward was not food related, however, both obese and non-obese children selected a food-related reward as opposed to a toy, when asked for their preference (Caleza et al., 2016). Recent research has implicated the role of self-regulation, specifically inhibitory control, on children's obesity rates and trajectories of adult BMI outcomes (e.g., (Bruce et al., 2011; Hughes et al., 2015; Schlam et al., 2013). Therefore, delay of gratification tasks that rely on food-related rewards, as in this current study, cannot fully be indicative of inhibitory control without inclusion of the role of child BMI.

Results of this study indicated no differences in delay ability and autonomic indicators between children from lower social risk (*prenatal*) and higher social risk (*community*) samples. This is in contrast to several studies finding such differences (e.g., (Evans & English, 2002; Raver et al., 2011; Sturge-Apple et al., 2016). Similar to Manuscript 1 (Chapter 4), maternal age was related to children's delay such that children who delayed the full task time had older mothers as compared to children who did not delay, however here, these associations attenuated after adjusting for other covariates. Socioeconomic context-dependent associations have been seen specifically with respect to vagal tone and delay of gratification: for children who lived in resource rich settings (i.e. middle-class) high vagal tone was associated with greater delay ability, while high vagal tone for children from lower socioeconomic families was associated with lower delay of gratification (Sturge-Apple et al., 2016). These researchers proposed that children's stress response system functioning and adaptation largely varies across socioeconomic risk strata; that is, what is considered as adaptive regulation in one risk context may be maladaptive in another.

Additionally, there were no correlations between mother's report of distress and autonomic indicators, and no differences in maternal distress between children who delayed vs. children who did not delay. This is consistent with results from Santucci and colleagues (2008) finding no effect of maternal depression on both children's vagal tone measures adaptive emotion regulation strategies. Extensive work has shown that maternal responsiveness and degree of mother-child dyadic connectedness predicts better self-regulatory capacity (Holochwost et al., 2018; Kiff et al., 2011; Lengua et al., 2007), however studies examining delay of gratification alone have not found such consistent associations. Recent literature has also indicated implications of maternal caregiving and sensitivity on children's stress response and reactivity, specifically ANS regulation (Bosquet Enlow et al., 2014). This study, in general, found no differences in autonomic indicators of regulation and reactivity between children from differing social risk strata or associations with maternal distress, but replication in a larger, more diverse sample with the inclusion of multi-level factors (i.e., environment, family dynamics, parenting-specific measures) would bolster study conclusions.

Autonomic regulation has been captured using several derived cardiac measures in the literature including basal (resting) indicators, task-related indicators, changes between basal and task (often referred to as reactivity), and changes during tasks. The majority of studies have examined basal and/or task-related reactivity (Calkins, 1997; Coulombe et al., 2019; Hinnant & El-Sheikh, 2009; Holzman & Bridgett, 2017; Kahle et al., 2018; Sturge-Apple et al., 2016; Sulik et al., 2015). The current study found no associations between pre-task values and delay ability and no differences in physiologic response to task and delay ability. Only changes in HR and RSA *during* the task, were related to delay ability, even after adjusting for maternal, child and sample characteristics. Children who delayed showed less increase in HR and more decrease in RSA from start of task to end of task, as compared to children who did not delay. Efficient suppression of vagal tone is necessary when attention is required for coping with environmental demands, often resulting in a decrease in RSA (and thereby increase in heart rate) in response to a challenge (Coulombe et al., 2019; Hinnant & El-Sheikh, 2009; Porges et al., 2007). The association between heart rate and RSA changes during the task and children's successful delay of gratification is likely an indicator of effective of vagal tone suppression.

Although there were no differences in point by point estimates or differences detected from the mixed effects regression models, after minute three children who did not delay the full task time seem to have more physiological disruption than children who delayed the full task time, who showed more stability in physiologic measures over task time (Figures 5.1 and 5.2). Children who delayed the full task time had physiologic patterning that has been reported in the literature as typically characteristic in response to a challenge, as discussed. Implications of changes in physiological indicators during task along with differential physiological regulation patterns seen start to indicate that children who eventually did not successfully delay, may have experienced the taxing nature of the delay task more so than children who were able to delay. The patterns seen here might reflect physiological modulation to adapt (or eventually not adapt) to the task at hand. Changes during the delay task may also measure the balance between levels of anticipation towards the snack reward over the course of the task and physiological modulation to that arousal to complete the task at hand.

Only 35% (n = 44) of children did not delay the full task period, with rapid attenuation in the number of children during the course of the task. Conclusions surrounding why differing physiological patterns existed are speculative due to the very small sample size over the task duration. However, results of these findings indicate that assessing differences in pre-task and task-related (overall mean heart rate or RSA during task) between children who delay and do not delay alone might miss some of the nuanced variation, or changes, between start and end of task that could be indicative of physiological flexibility to adapt and respond to a challenge. Further research is needed to validate the methodological contribution this study suggests by looking at change in physiological indicators during a delay task.

Three distinct classes of inhibitory control in response to the delay of gratification challenge task were identified based on differing intensities of coping strategies (motor activity, vocalizations) and anticipation. Children in the *active* (moderate motor activity, moderate vocalizations, high anticipation) inhibitory control class had the lowest odds of delaying the full task time as compared to children in *passive* (low motor activity, low vocalizations and moderate anticipation) and *disruptive* (high on all indicators) classes. Heart rate and RSA changes during the task, when examined separately, moderated the role between inhibitory control strategies and delay ability for children in the *active* inhibitory control class (moderate motor activity, moderate vocalizations, high anticipation). Children in the *active* class were more likely to delay if their heart rate decreased over the course of the delay task. Similarly, children who effectively suppressed RSA (decrease in RSA over task time) in the *active* class were able to delay the full task time. When examining heart rate and RSA changes during the task together, RSA changes during the task played a greater moderating role. These results are supported by the existing evidence base pointing to effective vagal suppression aiding inhibitory control and delay ability (Hinnant & El-Sheikh, 2009; Holochwost et al., 2018; Holzman & Bridgett, 2017).

The interpretation of increases and decreases of heart rate with respect to inhibitory control tasks is less clear. Heart rate responses could be a product of differing levels of children's impulsivity, activation of attentional processes, and/or a result of swift changes in somatic (or motor) activity (Holzman & Bridgett, 2017). Therefore, the reason for the relationship between which self-regulatory behaviors seen in this study (i.e., fidgeting, self-talk/distraction, attention orientation) and heart rate increases is not discernable. Interpretability of study results are strengthened by inclusion of RSA which provides a more robust indicator of the parasympathetic contribution than does heart rate alone. Engagement of vagal suppression for children whose anticipation towards the reward was high (*active* class) could help modulate some of the tug of war between volitional (motor and vocal regulation) and impulsigenic (anticipation) processes contributing to self-regulatory capacity.

This study has several strengths and contributions to the field. To my knowledge, this is the first study to analyze autonomic indicators concordant with volitional and impulsigenic processes in early childhood self-regulation. Here, behavioral and autonomic regulation was examined for children who both delayed and did not delay successfully, extending existing findings that have been limited to characterizing behavioral and autonomic regulation in tandem only among children who delay successfully (Wilson et al., 2009). In addition to the extended behavioral coding scheme to capture mechanisms underlying self-regulation (see Appendix A), this study examined pre-task, task-related, reactivity, and changes in physiologic variables during the delay task to characterize patterns of regulation contributing to inhibitory control. There are limitations to examining physiologic regulation during challenge/stressor tasks without adequately controlling for factors such as motor activity and self-soothing/regulatory behaviors (Cicchetti & Dawson, 2002; Porges et al., 2007). To address this, the current study controlled for concurrent levels of motor activity and self-regulatory behaviors. This study also assessed inhibitory control processes across two separate groups of participants from a more diverse sample than studies have typically included (Sturge-Apple et al., 2016). In addition, the current study had a larger sample size than previous work that has examined both behavioral and physiological regulation in tandem (Kahle et al., 2018; Santucci et al., 2008; Wilson et al., 2009).

It is also important to note limitations here. Many of the limitations in study design have been noted in Manuscript 1 (Chapter 4). Although this study included children from differing social risk strata, findings may have limited generalizability and should be considered preliminary. Additionally, the modest sample size, particularly for the non-delayers over the task duration, here may have prohibited the detection of further associations. The delay task captures a short period of time (up to 8 minutes) of autonomic and behavioral regulation only. Despite its brevity, this delay task has been used extensively in developmental research to predict a multitude of outcomes, such as reward-seeking behaviors, academic achievement, and socioemotional capacity (Hernandez et al., 2018; Supplee et al., 2011; Watts et al., 2018). Collecting autonomic measures provides salient information on underlying parasympathetic and sympathetic processes during the delay task, which has implications for children's socioemotional adjustment. Physiological measures provide a way to capture internal regulatory states and examine whether they align with behaviorally observable indicators of regulation, stress, and adjustment, and the implications of discordance between physiological regulation and observable expressions. Future work should capture autonomic influences on children's self-regulation, processes over multiple behavioral, emotional and cognitive tasks as well.

5.6 Conclusion

Developmental models of self-regulation highlight the importance of resisting impulses as a key requirement to health and well-being. Empirical research has identified vagal tone and regulation as potential physiological precursors to children's self-regulation development and capacity, however direction and magnitude of such associations have been relatively mixed to date. When examining behaviorally observable inhibitory control strategies (i.e. motor activity, vocalizations, and anticipation to reward), children who were unable to match their levels of regulatory strategies to their anticipation failed to delay gratification. However, in this study, underlying autonomic regulation played a role in aiding delay ability. The heterogeneity in unobservable processes underlying and accompanying behavioral regulation is important to capture. These results provide insights into how physiological and behavioral regulation work in tandem to modulate self-regulation and socioemotional capacity.

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5.9 Tables and Figures

Table 5.1

Sociodemographic Characteristics between Prenatal and Community Sample

	Prenatal Sample (n = 50)	Community Sample (n = 76)	
Variable	Mean (SD)	Mean (SD)	t or X^2
Maternal Age (years)	37.5 (4.5)	30.0 (6.9)	7.37***
Maternal Education (years)	18.1 (2.9)	12.6 (2.2)	11.38***
Married (%)	94	17.1	71.49**
Maternal Race and Ethnicity (%)			
Non-Hispanic white	78	11.3	
Hispanic white	4	0	70.0***
Black	12	86	
Other	6.0	2.8	
Child Age (years)	5.4 (.29)	5.5 (.27)	-2.79**
Girls (%)	60	52.6	.66
Child Race and Ethnicity (%)			
Non-Hispanic white	73.5	8.5	
Hispanic white	4.1	2.8	68.36***
Black	16.3	88.7	
Other	6.1	0	
In Pre-K or Kindergarten (%)	66	67	.02
Child BMI (% overweight/obese)	4	53	32.10***

Note. Child BMI is underweight/normal weight vs. overweight/obese; * $p < .05$, ** $p < .01$, *** $p < .001$

Table 5.2

Physiological Measures and Delay Ability

	Delayed (n = 82)	Did not Delay (n = 44)	
Variable	Mean (SD)	Mean (SD)	t or X^2
Heart Rate			
Instruction Period	94.3 (8.4)	93.5 (9.9)	-0.50
Overall Task	95.3 (8.5)	95.6 (11.3)	.17
Instruction to Task Change	.93 (4.4)	2.1 (7.1)	.98
Change during Task	4.7 (6.6)	30.3 (44.8)	3.77***
Respiratory Sinus Arrhythmia (RSA)			
Instruction Period	6.8 (1.3)	7.1 (1.9)	.81
Overall Task	7.0 (1.3)	7.1 (1.7)	.42
Instruction to Task Change	.17 (.78)	-.07 (1.4)	-1.0
Change During Task	-.35 (1.5)	1.8 (3.6)	3.81***

Note. Instruction period duration: M = 82.0 seconds, SD = 22.9, task period duration: M = 367.9 seconds, SD = 175.1; HR and RSA change during task reflect difference between end of task and start of task for each child; positive values indicate greater HR or RSA at end of task as compared to start of task . *** $p < .001$

Table 5.3

Interaction Effects of HR and RSA Changes During Task in Final Model (Model 3)

Inhibitory Control Class	Physio Variable	Logit[b]	SE	Logit/SE	*aOR*[c]
Passive	HR change During Task	-.01	.01	-1.4	.99
	RSA change During Task	.04	.03	1.4	1.04
Active	HR change During Task	.002	.002	1.0	1.00
	RSA change During Task	-.09	.03	-3.1	.92**
Disruptive	HR change During Task	-.02	.01	-1.6	.98
	RSA change During Task	.09	.09	1.0	1.09

Note. Model 3 examines the moderating role of HR and RSA changes during task on the relationship between latent inhibitory control classes and delay ability. b. estimates adjusted for maternal (age, education), child (age, sex, BMI (underweight/normal weight vs. overweight/obese) characteristics, sample (*prenatal* vs. *community*), and instruction duration. c. adjusted odds ratio of delay ability (delaying full task vs. not delaying full task). ** $p < .01$.

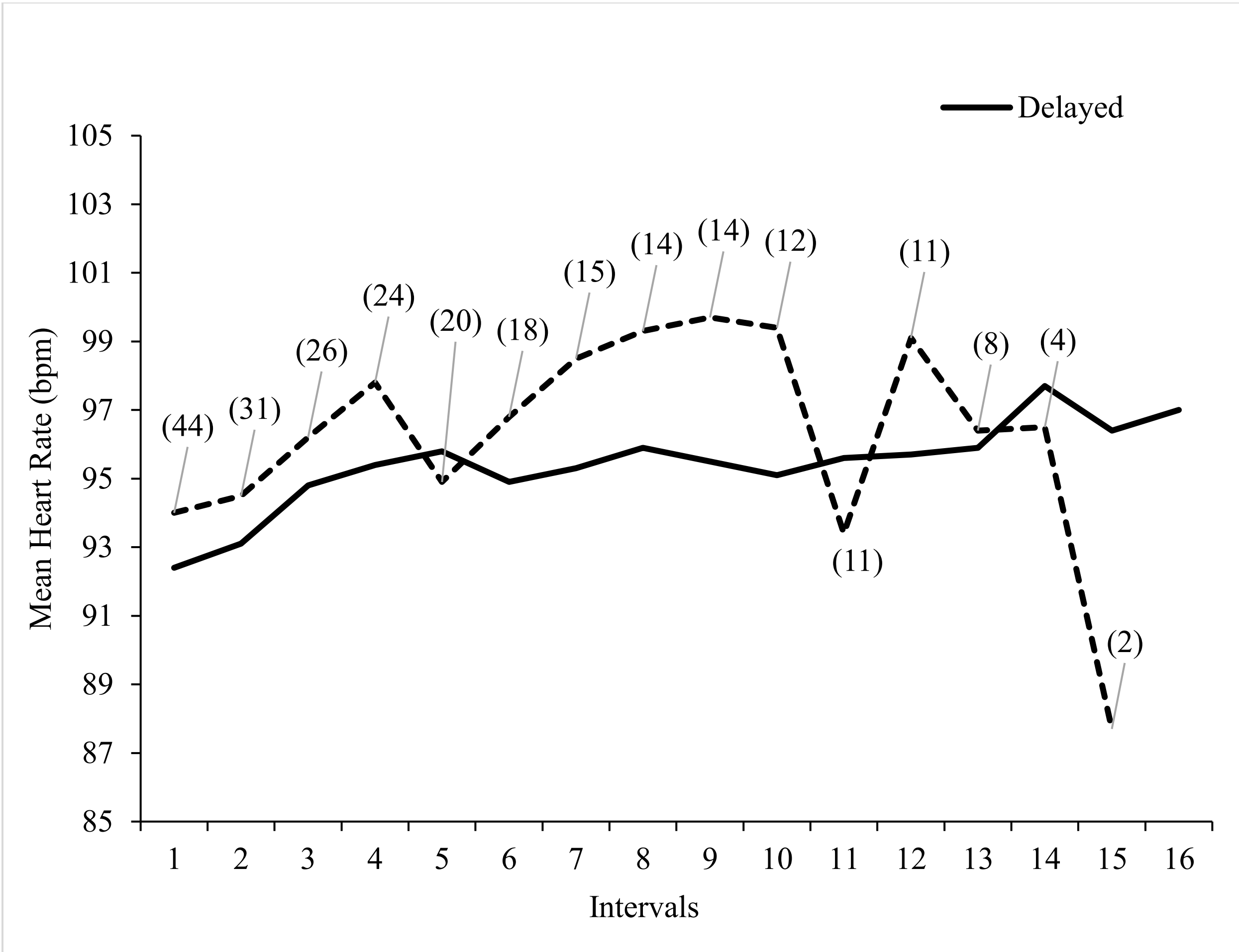

Figure 5.1

Patterns of Heart Rate during Delay of Gratification Task Comparing Children Who Delayed and Did Not Delay

Note. (Value) reflects decreasing sample size for children who did not delay at each respective interval; sample size for children who delayed is n = 82 across intervals.

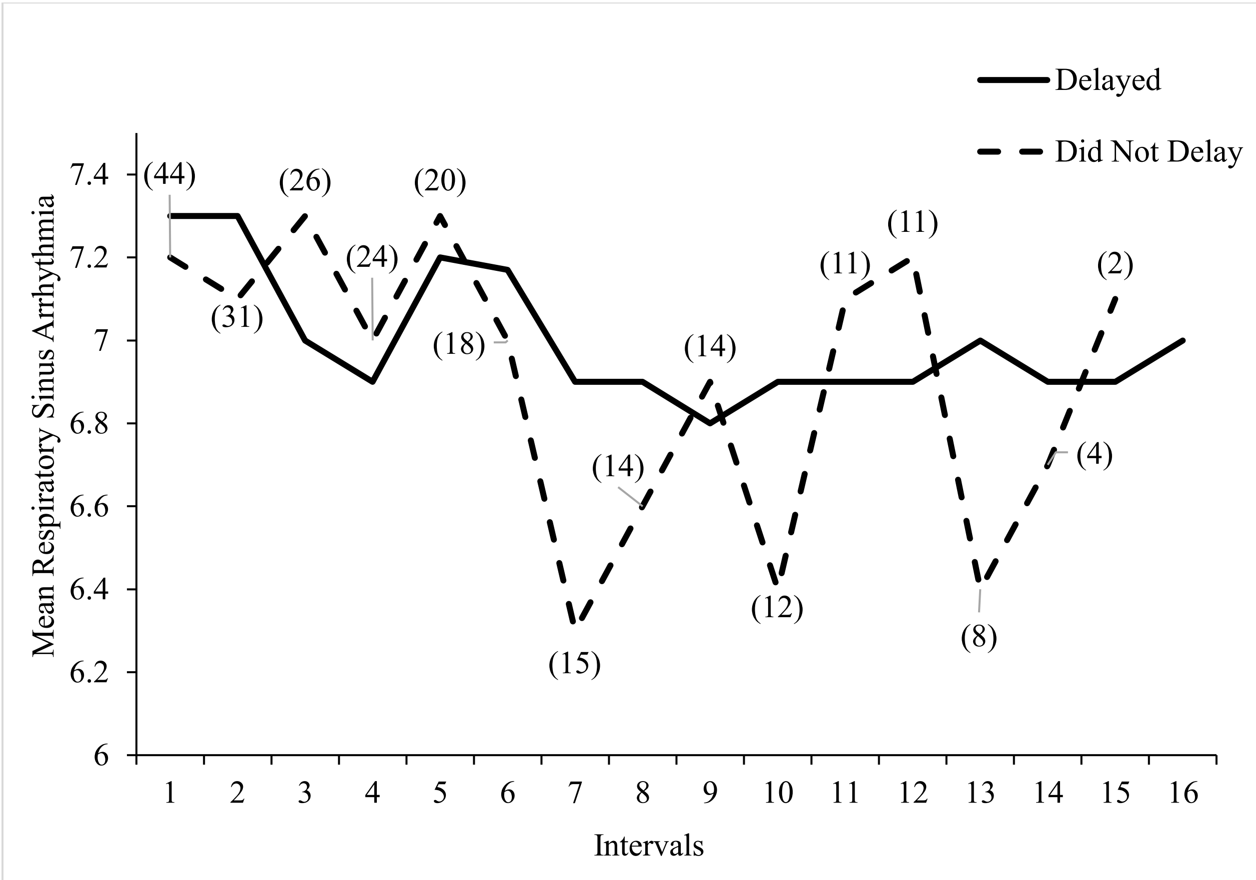

Figure 5.2

Patterns of Respiratory Sinus Arrhythmia during Delay of Gratification Task Comparing Children Who Delayed and Did Not Delay

Note. (Value) reflects decreasing sample size for children who did not delay at each respective interval; sample size for children who delayed is n = 82 across intervals.

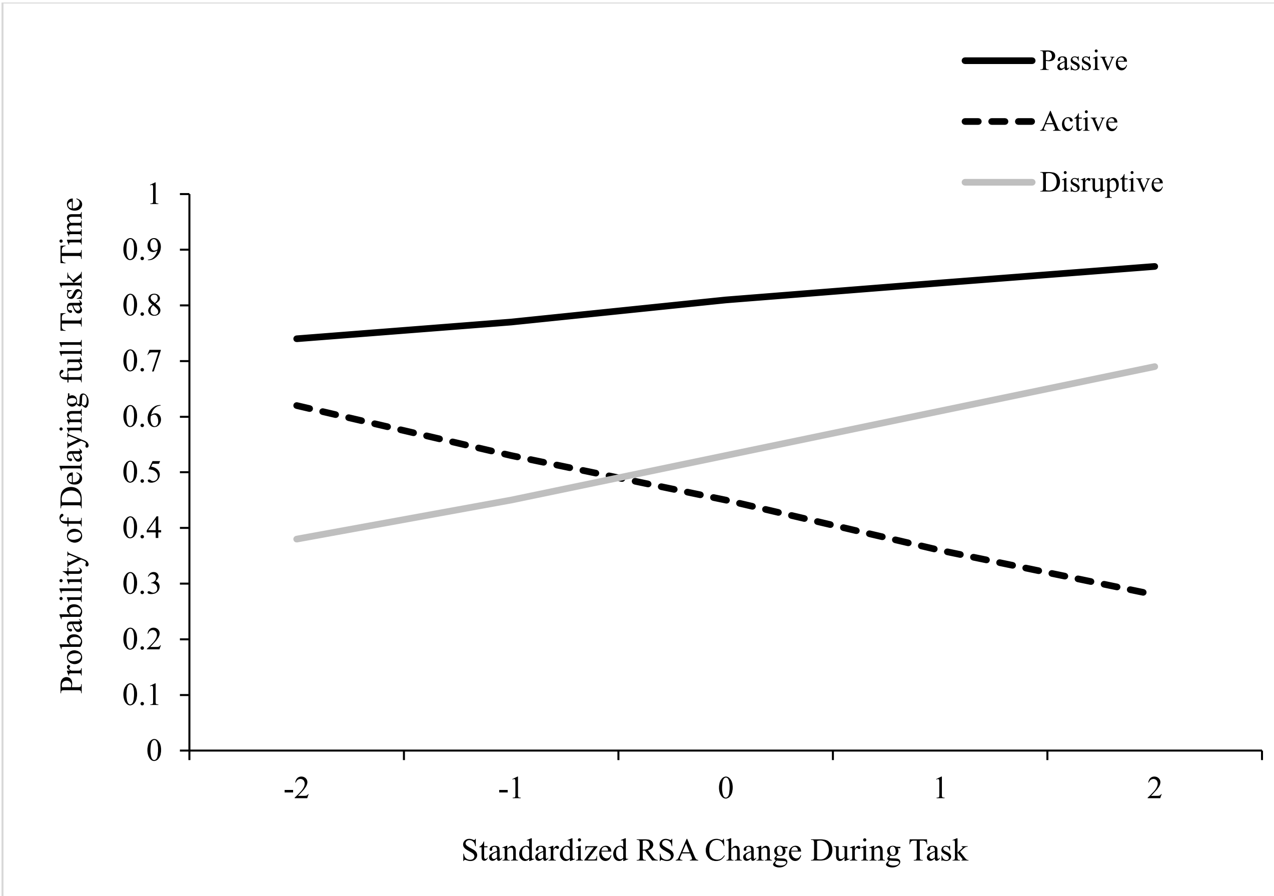

Figure 5.3

Inhibitory Control Classes and Delay Ability: Moderating Role of RSA based on Model 3

Note. HR and RSA variables were centered at $M = 0$, $SD = 1$. Results reported based on Model 3.

APPENDIX A.

Inhibitory Control Coding Scheme for Delay of Gratification Task

	Motor Activity	Vocalizations	Anticipation
Low (1)	Sitting still Small, minor natural repositioning in chair Small, discrete movements Smiling, mouth movements Resting head on table (not moving) Playing with fingers, nose, mouth, hair	No audible vocalizations Sighing Some mouth movements (either quiet or can hear something)	Spacing out, wandering attention Distraction (NOT using test materials) Eyes closed, head resting on back of chair No visible sign of frustration, sighing, etc.
Moderate (2)	Fidgeting (movement 3x or more, somewhat more disruptive than natural movements) Big mouth movements Small wiggling/dancing/rocking in chair Repeated repositioning/sliding in chair (>1/2 body); not seated but still in chair and wiggling	Quiet self-talk Repetitive vocalizations (verbal speech or non-verbal sounds), but not very disruptive Humming/singing in low voice	Gazing intensely at test materials Signs of some tension Sighing/slouching Head down on table Hands on head/face (either on table or oriented towards back of chair) Picking up snack 1-2 times
High (3)	Large repeated movements (3x or more, seen as more disruptive than moderate activity) Kicking legs (and/or making noise with kicking) Clapping hands disruptively Big wiggles/dancing Constant sliding and repositioning of body in chair (large movements, <1/2 body) Getting fully out of chair	Singing/repetitive vocalization in loud voice Consistent yelling/disruptive speech ("How's my heart doing?") Whistling loudly and continuously for at least 16 seconds	Touching and playing with test materials repeatedly (bell, plate) Almost ringing bell multiple times Licking, biting snack Visible frustration (facial expressions, body position, exaggerated sighing) Slamming fists on table, kicking out of frustration Visible excitement towards snack (smiling, smelling, etc.)

Note. Interval coding (i.e., every 30 seconds) was used to assess presence/absence and degree of motor activity and vocalizations. An overall code for anticipation was recorded after viewing video.

CHAPTER SIX

Manuscript 3

Child Development through Multiple Lens: Triangulating Maternal, Teacher and Child self-reported Behavioral and Emotional Problems in Middle Childhood

6.1 Abstract

The use of multiple informants in study of child behavioral and socioemotional development generates both convergent and divergent perspectives on the same aspects of development. The current study examined maternal, teacher, and child reports of behavioral and emotional difficulties using a standard scale (the Strengths and Difficulties Questionnaire) in a sample of sixty-four children aged 8-12 years. Multivariate linear and logistic regression models evaluated the degree to which women's reports of their own psychological distress (anxiety and depressive symptoms) affected ratings of their children, how maternal psychological distress related to teacher reports and child self-reports, and the role of observability of behaviors on informant discrepancies. Children reported greater behavioral and emotional problems than observed by mothers or teachers. With one exception, child and maternal ratings were not gender biased, but teachers consistently rated boys as having more difficulties than girls. Higher maternal psychological distress was associated with mothers reporting more emotional and behavioral difficulties for their child, $b = .39$, $t(59) = 3.00$, $p < .01$. Moreover, higher reported maternal psychological distress was related to children indicating themselves as having more difficulties, $b = .46$, $t(56) = 2.94$, $p < .01$, and to teacher reports of greater of child difficulties as well, $b = .29$, $t(39) = 2.07$, $p < .05$. Maternal and child sociodemographic characteristics and maternal psychological distress explained teacher-child informant discrepancies, but did not

explain mother-child discrepancies. Observability of behaviors elucidated some of the maternal-child discrepancies; mothers characterized their children as having significantly fewer internalizing behavior problems as compared to children (mother-defined 4.3% vs. child-defined 15.6%, $p < .01$). Results of this study indicate that mothers, teachers and children provide differing information on child socioemotional development. Child self-report offers critical information on internal states that may not be captured by proxy reports only. The importance of child self-report in middle childhood for early socioemotional problem identification is considered.

6.2 Introduction

Early detection, diagnosis and treatment of pervasive emotional and behavioral difficulties help assure that children reach their developmental potentials. Mental health problems, developmental disorders, and associated risk factors or outcomes, such as substance abuse and suicide, are crucial public health concerns that start to emerge during the middle childhood period or earlier but are often only caught later in adolescence once symptomology has progressed (Ghandour et al., 2019; Ozonoff, 2015). Reliance on proxy informants, most commonly parents, to provide information of children's psychological well-being is often not sufficient. As a result, research on measurement and identification of child and adolescent psychosocial risk factors has expanded to the use of multi-informant reports to accommodate multiple perspectives on child development (Riley, 2004; Vierhaus et al., 2018). Yet, questions remain on the role of child self-reports, particularly in middle childhood, in informing early measurement, policy and practice surrounding child socioemotional development and well-being.

Multi-informant reports in developmental research are advantageous because they provide information from several perspectives, including mothers, fathers, teachers, peers and the child themselves. Here, the focus is on descriptions of children's socioemotional development through the lens of mothers, teachers, and children. The discourse surrounding multi-informant approaches has focused on leveraging multiple viewpoints to capture a more complete picture of children's behavioral and emotional development across differing contexts (Vierhaus et al., 2018; Zapolski & Smith, 2013). However, this approach can generate differing descriptions of children's state and variation in behavioral and emotional well-being (Al Ghriwati et al., 2018; Dirks et al., 2012; Huber et al., 2019; Kraemer et al., 2003; Miller et al., 2014), which pose challenges for interpreting and integrating multiple diverging data sources into a cohesive assessment. Parents, teachers and children provide unique and non-interchangeable descriptions of children's state of emotional and behavioral well-being. Parents are in a good position to report on day to day variations in child behavior at home as they are most often proximally involved in a child's caregiving while teachers see a different range of child behaviors (i.e., behavioral control in the classroom, concentration and planning, and peer relationships) and evaluate these behaviors with respect to developmental milestones (De Los Reyes, 2013; Dirks et al., 2012).

The use of self-reports has been implemented most commonly in adolescence and late childhood. However, cognitive and developmental theory along with empirical evidence indicate that children can reliably report on their behavior and feelings as early as age 5 (Jardine et al., 2014; Riley, 2004). Based on maturational considerations, children have a unique awareness of their behaviors, struggles, and social perceptions (Riley, 2004; Ringoot, van der Ende, et al., 2015). For example, children may be able to perceive their own well-being, internal states, motivation, and emotional difficulties, but may not continuously express such matters to their parents/caregivers. As a result, reliance on proxy reports may miss unobservable aspects of child behavioral and emotional functioning. Age-appropriate methods for children to report on their well-being, even during early childhood, have been established (Deighton et al., 2014; Ringoot et al., 2013).

Middle childhood is a key period where social, emotional, behavioral, and physical competencies are honed and established to support successful transitions into adolescence (Laurens et al., 2017). Socioemotional competencies typically developed in middle childhood include establishing and maintaining positive social relationships, increased recognition and management of behaviors and emotions, and development of personality and self-esteem (DelGiudice, 2018). Middle childhood is often characterized by swift changes in social and physical pressures, and thus, is a developmental period that leads to the increased risk for future adverse health and well-being outcomes (Laurens et al., 2017). Development of child behavioral problems in middle childhood is influenced by multiple aspects of family environment, changes in socialization, and increasing encounters with new challenges, especially in middle school transitions (Dubois-Comtois et al., 2013; Essex et al., 2006; Laurens et al., 2017). Thus, this is an essential period to examine and support socioemotional development and psychosocial outcomes, specifically by the inclusion of child self-reported measures to further understand the nature of children's vulnerability during this developmental stage.

A number of studies have explored factors related to informant correspondence in reports of child behaviors and emotions, with the majority of studies focused on assessing information from two reporters (Al Ghriwati et al., 2018; Berg-Nielsen et al., 2003; De Los Reyes & Kazdin, 2004; Dotterer & Wehrspann, 2016; Human et al., 2016; Miller et al., 2014; Seiffge-Krenke &

Kollmar, 1998; Youngstrom et al., 2000). A highly-cited review, based on 119 studies with two or more informants conducted from 1967 to 1985, reported low to moderate correlations (*M* r = 0.28) between different reporters, such as parents and children or parents and teachers, on reports of child behavioral and emotional problems, with higher correlations (*M* r = 0.60) between informants who observed the child in the same context (i.e., mother-father) (Achenbach et al., 1987). A more recent meta-analysis (De Los Reyes et al., 2015) of 341 multi-informant studies published between 1989 and 2014 confirmed the modest concordance between cross-informant reports (*M* r = 0.28) of internalizing and externalizing behaviors.

Kraemer et al. (2003) proposed that informant discrepancies are a product of three components: a) variation in perspectives that informants have on children's behaviors; b) actual variation in children's behaviors across settings (e.g., school vs. home); and c) the extent that child behaviors are consistently expressed across informants' perspectives and settings (Kraemer et al., 2003). Using this framework, parent reports can be interpreted as a reflection of a child's behavior in the home context and across the continuum of development, teachers' reports reveal observations of child behavior expressed in non-home contexts (school) and in relation to developmentally similar peers, and child self-report is an amalgamation of one's own perceived behaviors expressed across various settings and a product of interpersonal dynamics and feedback from parents, peers, and teachers (De Los Reyes, 2013). Sociodemographic, family and child factors moderate the strength of informant convergence or divergence. These can include child age, child sex, family socioeconomic status, maternal characteristics (Duhig et al., 2000; Harvey et al., 2013; van der Veen-Mulders et al., 2017), maternal mental health symptomology (Madsen et al., 2019), observability of behavior characteristics (Vierhaus et al., 2018), and cultural and social aspects (Rescorla et al., 2007). Measurement and methodological issues such as using different questionnaires and methods of abstracting child emotional and behavioral constructs from reporters (i.e., questionnaires for parent, interviews for child) often prevail, thus making it difficult to directly compare developmental measures (Greco et al., 2016; Human et al., 2016; van der Toorn et al., 2010; Vierhaus et al., 2018). In general, findings surrounding which factors consistently explain informant discrepancies have been inconclusive (Van Roy et al., 2010).

Correspondence between parent and child reports on child socioemotional development is associated with parents' own psychological distress. In particular, maternal depression and anxiety symptoms are typically associated with inflation in reporting child problem behaviors (e.g., De Los Reyes et al., 2015; Gartstein et al., 2009; Madsen et al., 2019; Monti & Rudolph, 2017; Muller et al., 2011; Ringoot, Tiemeier, et al., 2015). Few studies have examined whether maternal psychological distress affects variation in child self-reports in children ranging from 10 to 12 years. In one, maternal depressive symptoms – but not anxiety – were significantly but modestly associated with maternal-child discrepancies on reports of child anxiety and affective problems (van der Toorn et al., 2010). In another, maternal depression symptoms were unrelated to teacher and child self-reports of behavior problems (Madsen et al., 2019). Interestingly, maternal-teacher and maternal-child ratings of child behavior problems were more concordant in the population of depressed mothers, versus non-depressed mothers (Madsen et al., 2019). The authors suggested that these associations could be due to two possibilities: one, women who are depressed rate their children as having more behavior problems as compared to women who are not depressed, while teachers rate similarly high problems for children of depressed and non-depressed mothers; and two, women who were depressed might be able to be in tune more with their children's behavior problems and thus, result in concordant ratings. These explanations were speculative in nature.

A relationship between observability of behaviors and multi-informant agreement has been proposed repeatedly, however empirical evaluations of this relationship are limited. Observability of behaviors has been defined both in terms of their external presentation and the likelihood that an informant would normally be able to witness the behavior (Cleridou et al., 2017; Vierhaus et al., 2018). Using clinician ratings of child internalizing or externalizing behavior problems in 11-17 year olds, Cleridou et al. (2017) noted greater concordance between parent-child ratings on the Strengths and Difficulties Questionnaire (SDQ) total difficulties score for children deemed as having more externalizing problems versus more internalizing problems (Cleridou et al., 2017). This coincides with meta-analytic studies finding higher multi-informant correlations when reporting on externalizing behaviors as compared to internalizing behaviors (Achenbach et al., 1987; De Los Reyes et al., 2015).

When informants were asked to rank each SDQ items in terms of observability, mothers perceived internalizing behaviors (i.e., emotional symptoms, peer problems) as less observable as compared to adolescents, who reported higher observability even on internalizing behavior constructs (Vierhaus et al., 2018). Adolescents in this study, therefore, deemed their internalizing behaviors as observable to proxy reporters, while proxy reporters (i.e., mothers) did not share this view. The more an item was rated as "observable" by both mothers and adolescents, the more agreement between reporters, regardless of if it was considered as internalizing or externalizing (Vierhaus et al., 2018).

The current study intends to add to the multi-informant methodology knowledge base by generating data pertaining to child socioemotional and behavioral challenges from three sources (i.e., mothers, children and teachers) using the same well-validated scale in middle childhood, an age that has been under-utilized in studies of this nature, particularly with respect to child self-report. This analysis aims to understand what each perspective provides and start to understand the way that multi-informant perspectives work together (or contrast each other) in order to inform larger psychosocial risk factor identification process. The current study compares and contrasts reports on child behavioral and emotional problems from mothers, teachers and children themselves specifically to: 1) examine factors related with concordance/discordance of reports; 2) evaluate the role of maternal psychological distress (i.e., anxiety and depression symptoms) in reporting and/or child self-perception by all informants; 3) address the role of observability/expression of behaviors on divergence of maternal, teacher and child self-reports;, and 4) describe the utility of child self-report in middle childhood as a tool for early psychosocial risk assessment by examining concordance/discordance with information from maternal reports.

6.3 Methods

Participants

Participants consisted of a subset of families originally identified through their participation in a study commencing in the prenatal period with periodic longitudinal follow-up. Participants were drawn from the two cohorts, born between 2007 and 2011, and last seen when children were aged 5. Of that sample of 146 families, 134 mother-child pairs were considered for participation based on age eligibility (child age from 8 to 12 years) at time of data collection; an additional 2 children were excluded due to previously diagnosed developmental conditions. Fourteen sibling pairs were included in the original sample; only one sibling (typically the older and/or age eligible child) was included in this study. This resulted in a final potential sample of 118 mother-child pairs. All children in this sample were the mothers' biological children.

Families were contacted between March 2019 and September 2019 using most recent available contact information. Nearly 25% (*n* = 28) of families had outdated contact information (e.g., email bounced back, phone number no longer in service, no alternate contact was found). Of the remaining 90 families, 69 mother-child pairs responded and agreed to participate, one family declined, and 21 families failed to respond. Of the 69 families who agreed to participate, 67 mothers (97%), 64 children (93%) and 47 (68%) teachers ultimately participated. There were no differences in maternal age, maternal education, maternal race, maternal marital status and child sex between responders and non-responders, therefore analyses were restricted to responders only and weighting or further analytic techniques to account for non-responders were not used.

Sample Characteristics

On average, women were well-educated (*M* = 17.6 years education, *SD* = 2.1), with 66% having a master's or higher degree, mature (*M* = 43.2 years of age, *SD* = 4.8), married (90%), and predominantly non-Hispanic white (76%) with the remainder distributed as 9% white Hispanic; 6% African American; 7% Asian; and 1% multi-racial. Children were also predominantly non-Hispanic white (69%) but more likely to be multi-racial (8%). Fifty-three percent of the children were female and 61% were firstborn. At the time of data collection, 39% of children were in elementary school and 61% were in middle school; ages ranged from 8-12 years (*M* = 10.2 years, *SD* = 1.6).

Procedures and Measures

Mothers and children who agreed to participate in the study were sent separate links to maternal and child questionnaires; 2 mothers requested paper versions. Mothers and children were directed to complete the questionnaires independently. Most (83%) of children reported completing questionnaires on their own, the remainder with help from their mothers. As expected, those children were more likely to be in elementary school ($X^2(1, N = 64) = 5.01$ $p < .05$). Teacher questionnaires were mailed to the participating families who were asked to deliver them to the child's primary teacher (elementary school) or science teacher (middle school). Teachers returned questionnaires by mail. Sixty-five teacher questionnaires were provided to the participating families, two families did not agree to teacher questionnaires. Of the 65 potential teachers, 47 ultimately responded. No demographic data (i.e., teacher sex, age, etc.) were collected from teachers. Most (78%) children went to public schools and responding teachers were distributed among primary (49%), science (45%), or other subjects (6%). On average, teachers reported knowing the child they reported on for 12 months at time of questionnaire return (*range* = 5-60 months; *SD* = 9.2).

Strengths and Difficulties Questionnaire. Parent, child self-report and teacher versions of the Strengths and Difficulties Questionnaire (SDQ) were used to assess child emotional and behavioral regulation. The SDQ is a focused behavioral screening questionnaire for 4-17 year olds (Goodman, 1997), consisting of 25 questions, with Likert scale responses, organized around five behavioral constructs (Emotional symptoms, Conduct problems, Hyperactivity/Inattention, Peer relationship problems, and Prosocial behaviors) and a Total Difficulties score, derived by summing the first four subscales (Goodman, 1997).

In addition, Internalizing (Emotional symptoms + Peer problems) and externalizing (Hyperactivity/Inattention + Conduct problems) composites were based on suggested SDQ scoring (Goodman et al., 2010). U.S normative SDQ scoring bands were used to categorize maternal, teacher, and child self-reports into high internalizing/high externalizing (top 20 percent) or low internalizing/externalizing (bottom 80 percent) groups (Bourdon et al., 2005).

The SDQ has been extensively validated cross-culturally, with different age groups, informants and various translations. Psychometric properties of the SDQ across multiple studies reveal adequate internal consistency: parent report, α = 0.71 (*range* =.57-.85); teacher report, α = 0.81 (*range* = .70-.88); and child self-report, α = 0.66 (*range* = .41-.81) (James, 2017; Stone et al., 2010). There was similar internal consistency in this study's sample, to that reported in the literature, with the exception of higher internal consistency for child self-report here: maternal report, α = 0.73; teacher report, α = 0.79; and child self-report, α = 0.79.

The State-Trait Anxiety Inventory. State-Trait Anxiety Inventory, Form Y1 (STAI-Y1) is designed to assess state anxiety (Spielberger et al., 1968). This measure is often used as an indicator of caregiver distress and has good psychometric validation. The STAI-Y1 includes 20 items relating to how the respondent is feeling in the moment, rated on 4-point scales (Spielberger et al., 1968) and, after reverse scoring for some items, summed. Higher scores indicate higher levels of state anxiety.

Center for Epidemiologic Studies Depression Scale. Center for Epidemiological Studies-Depression (CES-D) is a measure of depressive symptoms (Radloff, 1977). Respondents rate how often, over the past week, they experience 20 symptoms that are associated with depression (feeling alone, trouble concentrating, fatigue and restlessness, etc.) on 3-point scales, and summed. Higher scores indicate more depressive symptoms (Radloff, 1977).

Data Analyses

Informant differences (mother, teacher, child) on each of the five SDQ scales and Total Difficulties were tested via paired sample t-tests. Inter-rater associations were conducted using Pearson correlation coefficients. Sensitivity analyses were run to examine differences in correlations between maternal and self-reported constructs for children who reported having maternal assistance to complete questionnaires versus children who reported completing the questionnaire independently; this was done to assess the issue of non-independence for those children who had help from their mothers. The correlation between maternal-child self-reports for children who completed the questionnaire on their own compared with children who needed the help of their mother was not significantly different. Bivariate and multivariable linear regression analyses were utilized to identify maternal (age, education) and child (age and sex) characteristics that explained variation in SDQ reports. Bivariate linear regression analyses were conducted for all maternal, child, and teacher SDQ constructs and Total Difficulties score separately. Adjusted linear regression analyses were conducted for the SDQ Total Difficulties score.

Bivariate and multivariable linear regression models were fit to assess the relative contribution of maternal and child factors, and maternal psychological distress on informant discrepancies using mean differences (deltas) in maternal-child, maternal-teacher, and teacher-child SDQ Total Difficulties scores as the outcome of interest. Children were grouped by patterns of Internalizing and Externalizing problems; discordance among maternal, teacher and child defined behavior groups and associations with maternal and child characteristics were examined through paired t-tests, ANOVA, Kappa statistics, Fisher's exact tests, and tests of proportions. All analyses were conducted using Stata 13.1 (StataCorp., 2013).

6.4 Results

Mean values and pairwise comparisons of SDQ ratings among reporters are presented in Figure 6.1. Children rated themselves significantly higher on Emotional symptoms, $t(63) = 2.95$, $p < .01$, Conduct problems, $t(63) = 3.89$, $p < .001$, Hyperactivity, $t(63) = 4.27$, $p < .001$, and Total Difficulties, $t(63) = 4.82$, $p < .001$, than did their mothers. Similarly, children also reported themselves significantly higher on Emotional symptoms, $t(46) = -4.49$, $p < .001$, Conduct problems, $t(46) = -3.55$, $p < .001$, Hyperactivity, $t(46) = -3.48$, $p = .001$, and Total Difficulties, $t(46) = -4.45$, $p < .001$ than did their teachers. Mothers and teachers did not differ significantly on any of the SDQ ratings.

Table 6.1 contains inter-rater SDQ correlations. Overall, there were moderate to strong correlations between maternal, child and teacher reports on SDQ ratings (*r*s *range* = 0.29 - 0.63, *p*s < .05). Correlations between maternal and child reports on Peer problems tended to be lower than maternal-teacher and teacher-child associations, although differences between the correlations were not significantly different. This was also true for maternal-teacher reports on Prosocial behaviors and child-teacher reports on Conduct problems and Prosocial behaviors.

Sociodemographic Moderating Influences on Multi-Informant SDQ Ratings

No significant associations were detected between maternal SDQ ratings and maternal education, child age, child sex, birth order, and parity. Maternal age was only significantly associated with one rating, Hyperactivity, $r(65) = -0.29$, $p < .05$, such that older mothers rated their child as having fewer problems with hyperactivity and inattention.

Child ratings were somewhat more influenced by family context such that children rated themselves as having more Emotional problems if their mother had completed fewer years of education $r(62) = -.27$, $p < .05$, or if they had siblings, ($M = 1.14$, $SD = .34$) versus only child ($M = 2.96$, $SD = .31$), $t(62) = 2.04$, $p < .05$. Children also reported more Peer problems if they were the first born child ($M = 1.84$, $SD = .31$) versus later born ($M = .72$, $SD = .19$), $t(62) = 2.72$, $p < .001$. In general, there were no sex differences in child self-report, with the exception of girls rating themselves higher on Prosocial behaviors ($M = 9.05$, $SD = .18$) than boys ($M = 7.8$, $SD = .28$), $t(62) = -3.79$, $p < .001$.

Teachers SDQ ratings were unrelated to classroom variables (i.e., child grade, type of school, and duration that the teacher knew the child) or child age. However, there were consistent differences in teacher SDQ ratings by child sex: teachers rated boys as having more Conduct problems, $t(21.9) = 2.29$, $p < .05$, Hyperactivity, $t(26.5) = 3.32$, $p < .001$, Peer problems, $t(22.4) = 2.38$, $p < .05$, and Total Difficulties, $t(26.1) = 3.08$, $p < .01$, as compared to girls. and fewer Prosocial behaviors, $t(45) = -2.78$, $p < .01$.

Maternal Psychological Distress and Maternal, Child and Teacher SDQ Ratings

Generally, based on scale norms, women reported low to moderate state anxiety symptoms (STAI-Y1) ($M = 28.8$ points, $SD = 7.2$, *range* = 20-51) and low to moderate depressive symptoms (CES-D) ($M = 7.0$ points, $SD = 6.5$, *range* = 0-32). Women's anxiety and depressive symptoms were unrelated to their age, education, child age, child sex, birth order of child and child sibling status, but as expected, women's STAI and CES-D scores were significantly correlated, $r(64) = .66$, $p < .001$. Correlations between maternal SDQ ratings of children and maternal psychological distress are presented in Table 6.2. Women who reported higher anxiety symptoms rated their children higher on Hyperactivity, Peer problems and Total Difficulties, and lower on Prosocial behaviors. Correlations between maternal depressive symptoms and maternal SDQ ratings were significant for all SDQ scores, with the exception of Prosocial behaviors; women with higher depressive symptoms rated their children more negatively on all dimensions.

Table 6.3 presents bivariate associations between child and teacher SDQ scores in relation to maternal anxiety and depression. Maternal anxiety was unrelated to child self-report with one exception: children of women with higher anxiety reported themselves to exhibit fewer prosocial behaviors. However, children of women with more depressive symptoms reported themselves higher on Conduct problems, Hyperactivity, Peer problems, and Total Difficulties, and lower on Prosocial behaviors. Teachers rated children of women with higher anxiety symptoms as having more Emotional symptoms, Conduct problems, Hyperactivity and Total Difficulties. Teachers also rated children of women with higher depressive symptoms as having more Peer problems and Total Difficulties.

Adjustment for covariates (i.e., maternal age, maternal education, child age, child sex and maternal state anxiety) in the prediction of Total Difficulties revealed that maternal depressive symptoms explained a significant proportion of variance in their reports of child Total Difficulties, $R^2 = .31$, $F(6, 59) = 4.51$, $p < .001$; $b = .39$, $t(59) = 3.00$, $p < .01$. Maternal depressive symptoms also explained a significant proportion of variance in the child's self-report of Total Difficulties, $R^2 = .21$, $F(6, 56) = 2.53$, $p < .05$; $b = .46$, $t(56) = 2.94$, $p < .01$ after adjustment. In both instances, higher maternal depressive symptoms were associated with higher rating of child Total Difficulties.

With respect to teacher ratings, child sex, maternal education, and maternal anxiety symptoms all explained a significant proportion of variance, $R^2 = .41$, $F\ (6, 39) = 4.59$, $p = .001$. After adjustment, boys had more Total Difficulties than girls, $b = -4.99$, $t(39) = -3.27$, $p < .05$ as did children of women with less education, $b = -.92$, $t(39) = -2.57$, $p = .01$. In contrast to the preceding results, maternal anxiety, not depressive symptoms, was significantly associated with teacher ratings of total child difficulties, $b = .29$, $t(39) = 2.07$, $p < .05$.

Informant Discrepancies in SDQ Reports

Bivariate and multivariate linear regression models were fit to examine factors related to the inter-rater discrepancies in SDQ total difficulties score. Since there were only significant difference between maternal-child and teacher-child total difficulties scores, separate regression models were fit for maternal-child and teacher-child total difficulties deltas as outcomes. Maternal-child deltas were constructed by subtracting child self-reported total difficulties from maternal reported total difficulties and teacher-child deltas were constructed by subtracting child self-reported total difficulties from teacher reported total difficulties.

There were no significant associations between the maternal-child total difficulties delta and maternal and child demographic characteristics and maternal psychological distress when looking at bivariate models or the fully adjusted linear regression model. In contrast, for teacher reports, bivariate analyses revealed a significant association between child sex and teacher-child difference (discrepancy) in total difficulties score, such that there was greater teacher-child discrepancy if the child was a girl as compared to a boy, $b = -5.15$, $t(45) = -3.12$, $p < .01$. The results of the fully adjusted regression analysis indicated that three predictors explained a significant proportion of variance in teacher-child total difficulties delta ($R^2 = 0.33$, $F(6, 39) = 3.14$, $p = .01$). Child sex remained a significant predictor of teacher-child discrepancy in the fully adjusted model. Again, there was a greater teacher-child discrepancy in total difficulties score if the child was a girl as compared to if a child was a boy, $b = -5.14$, $t(39) = -3.07$, $p < .01$, adjusting for maternal and child-level factors. There was a greater adjusted teacher-child discrepancy in total difficulties score if the child had a mother with more depressive symptoms, $b = -.45$, $t(39) = -2.86$, $p = .01$. Additionally, there was a greater adjusted teacher-child discrepancy in Total Difficulties score if the child had a mother with lower state-levels of anxiety, $b = .34$, $t(39) = 2.20$, $p < .05$.

Patterns of Maternal, Child and Teacher reported Internalizing and Externalizing Behaviors

Internalizing and Externalizing scale scores and standardized cutoffs (see SDQ section in Methods), were used to distribute children into 4 groups: 1. low Internalizing *and* low

Externalizing (Low/Low); 2. High internalizing and low externalizing (High Internalizing); 3. low Internalizing and high Externalizing (High Externalizing); and 4. high Internalizing *and* high Externalizing (High/High). Separate groups were created based on mother-rated (mother-defined) and child self-reported (child-defined) SDQ constructs. Standardized percent cut-offs (bottom 80% = low, top 20% = high) were applied to maternal and child self-reported scores separately. This approach was used to characterize patterns of maternal reports and child self-reports to parse out the role of observability. Teacher rating were excluded from categorization given the small sample size. Distribution of behavior groups by reporter is presented in Figure 6.2.

Maternal age, maternal education, child age, child sex, and maternal anxiety did not differ among the 4 behavior groups, for both mother-defined and child-defined groups. However, maternal depressive symptoms and mother-defined behavior groups were related, $F(3, 63) = 5.17$, $p < .01$. Results of post-estimation pairwise comparisons indicated that women who rated their child as High/High also reported more depressive symptoms as compared to women who rated their child as Low/Low, $t(63) = 3.21$, $p = .01$. No other differences in maternal depressive symptoms and mother-defined behavior groups were present. Similarly there was a significant association between maternal depressive symptoms and child-defined behavior groups, $F(3, 60) = 3.28$, $p < .05$, such that children who rated themselves as High/High tended to have mothers with higher depressive symptoms as compared to children who rated themselves as Low/Low, $t(60) = 3.12$, $p < .05$.

Inter-rater agreement between mother-defined and child-defined groups was examined using a weighted Kappa statistic to account for the degree of disagreement. Mother-defined and child-defined behavior groups had fair agreement ($\kappa = .42$, $p < .001$). There was good mother-child agreement on Low/Low designations (87.2%) and, although the sample sizes are small, some agreement on child reports of High Externalizing (28.6%) and High/High (42.8%). Mothers and children did not agree on reports of High Internalizing behaviors. Using mother-defined groups, the majority of inconsistencies stemmed from mothers rating their children as Low/Low (n = 12) while children rated themselves otherwise (n = 8 High Internalizing, n = 3 High Externalizing, n = 1 High/High). There were no bivariate differences in maternal age, maternal education, child age, child sex, or maternal anxiety between these 12 mothers and the 34 other mother-child pairs who consistently reported behaviors in the Low/Low group. However, these 12 mothers had higher depressive symptoms as compared to the mothers who consistently reported in the Low/Low group with their child, $t(44) = -2.14$, $p < .05$.

Mother-defined and child-defined behavior groups were categorized into "consistent" (mother and child defined child similarly, n = 39) vs. "inconsistent" (mother and child defined child differently, n = 25) groups. Bivariate and multivariate analyses revealed no associations with maternal age, maternal education, child age, child sex, maternal anxiety, or maternal depression between the consistently and inconsistently reporter-defined child behavior groups.

Finally, this study explored whether the inconsistencies in mother-child reports could be explained by the "observability" (or expression) of behaviors. Fisher's exact test and test of proportions were used to examine the source of inconsistencies between mother-defined and child-defined groups. Maternal and self (child) distribution into the 4 categories significantly differed $p = .001$, such that mothers characterized their children as having significantly fewer internalizing behavior problems as compared to children (mother-defined 4.3% vs. child-defined 15.6%, $p < .05$). Mothers tended to report their child as High Externalizing (13.4%) as compared to children who tended to report themselves as High Internalizing (10.9%); however, the difference between these groups was not significant.

6.5 Discussion

The current study findings reveal that: 1) children reported more socioemotional difficulties than mothers and teachers, and this discrepancy could not be fully explained by the "observability" of child behaviors; 2) maternal-child discrepancies in reporting were not related to maternal, child characteristics or maternal anxiety and depressive symptoms while teacher-child discrepancies could be explained by child sex and maternal psychological distress (anxiety and depressive symptoms); and 3) women's psychological distress affected maternal, child self-report and teacher ratings of child difficulties, even after accounting for other maternal and child characteristics.

Overall, children rated themselves as having more emotional symptoms, conduct problems, hyperactivity, and total difficulties as compared to maternal and teacher report. Children can be the most accurate reporters of emotional and behavioral states, but oftentimes are not asked to provide information or play a leading role in the conversation surrounding their own socioemotional well-being (Greco et al., 2016). Actively including children in the monitoring of their own well-being is essential to collecting information that that they might want to voice but may not always have the opportunity to share with parents, teachers, and healthcare providers. Child self-report may serve as an invaluable early risk assessment tool for those types of behavioral, social and emotional problems that may, if left unheeded, generate more serious psychological consequences. Several studies have examined methods of capturing child self-report with respect to mental health and psychopathy (Greco et al., 2016). Greco and colleagues (2016) reviewed existing self-report tools and found 33 valid and reliable measures, specifically designed for children 8-15 years, across various disciplines that could be informative for early mental health screening and diagnosis. Similarly, a multi-country study examining the utility of a child mental health self-reported questionnaire in children 6-11 years of age found high cross-country reliability in a computerized child mental health self-reported questionnaire, providing some evidence into socially and culturally comparable measurement tools as well (Kuijpers et al., 2016). The discussion here, therefore, is not whether adaptable, valid and reliable, self-report tools exist, but rather how to best use existing self-report measures in practice to provide quality care. Once children are capable and able to report on their own behavioral and emotional states, we should challenge the conventional notion that a multi-informant approach is methodologically more rigorous, and rather focus on leveraging accurate tools for child self-report.

In general, mothers reported children having lower internalizing behavior problems as compared to how children reported themselves. The majority of inconsistencies between maternal and child reports were when mothers reported their children as having low behavior problems, but children identified themselves as having high internalizing, high externalizing or both internalizing and externalizing behavior problems; again, children were reporting more behavioral and emotional problems as compared to mothers here. Some of these inconsistencies seemed to be driven by maternal depressive symptoms, such that mothers with higher depressive symptoms reported their child as having fewer difficulties as compared to mothers with lower depressive symptoms. Due to sample size constraints, analysis of inconsistencies was limited to contingency tables. Further analysis of the moderating effects of covariates and observability on informant discrepancies is needed. Regardless, evidence from this study shows that children have differing perspectives on their socioemotional states than other typically referenced reporters (parents, teachers), even when grouping and identifying children at highest propensity for internalizing/externalizing behaviors or those who have more seemingly "observable" difficulties.

Mothers and teachers reported similarly across all SDQ constructs. There were no differences in maternal SDQ ratings by child sex. Girls, however, reported themselves as more prosocial than boys and teachers rated boys as having more behavioral problems overall than girls. Though directionality of sex differences in child self-report and teacher reports in the literature is mixed, there were sex differences in child self-report and teacher report consistent with prior research (i.e., Miller et al., 2014; van Tetering & Jolles, 2017). Despite significant differences between maternal-child SDQ ratings, none of the selected maternal and child variables including maternal psychological distress, could explain the informant discrepancies. However, teacher-child discrepancies could be explained by child sex, maternal anxiety, and maternal depressive symptoms. Teachers and children had greater discrepancies in total difficulties score if the child was a girl. Teachers tended to report girls as having fewer difficulties as compared to boys. Yet, child self-reports indicated that girls reported significantly more difficulties for themselves than their teachers reported for them. The discrepancy seen here could be a product of teachers reporting differently on boys vs. girls, that are not reflected in child self-reports.

Teachers and children agreed more in their reports of total difficulties if the child's mother had more depressive symptoms. This may reflect the effect of maternal depressive symptoms on child behaviors that even a teacher can pick up on. Interestingly, teacher-child discrepancy in total difficulties score was greater if the child had a mother with lower anxiety symptoms. One possible explanation for the discrepancy seen here is that children with more anxious mothers report themselves as having more socially-related problems (i.e., low on prosocial scale), which could also be identified easily by teachers due to the nature of observations in a classroom setting. Further research is needed to confirm why lower levels of maternal anxiety relate to more teacher-child discrepancy.

Although women in this sample reported moderate to low anxiety and depressive symptoms, maternal psychological distress was strongly related to maternal, child and teacher SDQ ratings. Women's depressive symptoms significantly predicted maternal SDQ ratings, even after adjusting for other maternal and child factors. Women's psychological distress in relation in maternal report has been extensively examined in the literature (Madsen et al., 2019; Muller et al., 2011; van der Toorn et al., 2010). Similar to findings in other studies, maternal psychological distress inflated maternal report of child behavior and emotional problems. When maternal anxiety and depressive symptoms were examined together, maternal depressive symptoms played a greater role in explaining variations in maternal SDQ ratings.

Beyond the influence of maternal distress biasing maternal reports, children who had more anxious mothers reported themselves as expressing fewer prosocial behaviors, whereas children who had mothers with more depressive symptoms reported themselves as having more conduct, hyperactivity and peer problems, in addition to total difficulties. Maternal depressive symptoms remained a significant predictor of child SDQ ratings, even after controlling for child and maternal factors. The current study results are similar to Dubois-Comtois et al. (2013), who reported that children rated themselves as having more internalizing and externalizing problems if their mother reported higher levels of psychological distress (Dubois-Comtois et al., 2013). The results from the current study add to the literature base as there are few studies examining the role of maternal psychological distress on child self-report specifically.

Maternal depressive symptoms again played an interesting role when examining patterns of maternal-defined and child-defined emotional and behavioral symptoms. Mothers who rated their child as high on both internalizing and externalizing problems had more depressive symptoms compared to mothers who rated their child as low on both dimensions. Additionally, children who rated themselves as having high levels of both internalizing and externalizing problems had mothers with more depressive symptoms than children who rated themselves as low on both dimensions.

Exposure to maternal depressive and anxiety symptoms in childhood is a well-researched risk factor for child emotional and behavioral difficulties (Goodman et al., 2011; Herba et al., 2013; Monti & Rudolph, 2017). One explanation is rooted in shared genetic factors of anxiety and depressive disorders (Axelson & Birmaher, 2001). Children of mothers who have a higher propensity for depressive symptoms or anxiety might have more shared genetic variability relating to their own propensity for anxiety and depression development. Twin and family studies specifically examining genetic components of anxiety and depression show significant overlap in neurobiological circuits involved in modulating the expression of such mental health disorders (Axelson & Birmaher, 2001). Future studies looking at the role of maternal psychological distress on biological versus adoptive child self-reports are needed to further elucidate such pathways.

Another potential explanation for even relatively low levels of maternal psychological distress, as seen in this sample, to translate into child self-perception of behavioral and emotional problems is via differing parent-child interactions/relationships (De Los Reyes & Ohannessian, 2016; Van Roy et al., 2010). That is, more distressed women may interact with their children differently than less distressed women, contributing to and reinforcing more negative child self-perceptions. Thus, the quality of mother-child interactions is be an essential pathway that maternal adjustment problems transmit to her child (Dubois-Comtois et al., 2013). The effect of maternal psychological distress on child self-reported behavior and emotional problems may be partially a product of the type and quality of interactions between the mother and her child; however, further evidence is needed to support this.

Taken together, it is important to consider whether maternal depressive symptoms and anxiety result in measurement error (biases in reporting), are a result of mother's heightened awareness of her child, are a product of shared genetic variation related to depression and anxiety, or transmit through mother-child parenting interactions. From this current study, the nuanced role that maternal psychological distress plays is not determinable, but research in this field would benefit from methodically examining such avenues of influence. It is imperative to examine the multi-faceted effect of maternal psychological distress on child socioemotional development, beyond only relaying the measurement bias component which has been repeatedly examined in the literature.

This study expands the literature by utilizing teacher report as a way to validate the associations between maternal psychological distress and child emotional and behavioral development. Teachers also rated children as having more behavior and emotional problems if the child's mother had higher anxiety or depressive symptoms. Although teacher report is likely not directly impacted by maternal factors, teachers serve as an important reporter who observes and assesses a child's behavior in a structured setting, in relation to other children in similar developmental periods (van Tetering et al., 2018). In this study, mothers were asked to provide the teacher questionnaire to either the homeroom (elementary school children) or science teacher (middle school children) in effort to capture teacher ratings across a range of classroom interactions, including group/lab work. Here, it is seen that maternal distress may affect child behavior to a degree that even an independent reporter, such as a teacher, can identify.

One strength of the present study is the use of the well-validated Strengths and Difficulties Questionnaire (SDQ) to capture child behavioral and emotional problems. Parent, teacher and child self-report measures of the SDQ have the same items and subscales, allowing for parallel and direct comparison across informants. This study also used U.S based SDQ normative bands to categorize children with high and low propensities for internalizing and externalizing emotional and behavior problems. The results here contribute to the literature base in a unique way as there are few studies that have empirically looked at whether concordance between multiple informants can be explained by the type of constructs reported on rather than sociodemographic characteristics alone.

Another strength of this study is examining maternal psychological distress in relation to maternal, child and teacher reports. This is one of the few studies to examine the effect of maternal anxiety and depressive symptoms directly on child self-report and to use teacher report as a way to validate relationships seen. The majority of research surrounding multi-informant reports utilizes self-report in adolescence; in contrast, this study measured behavioral and emotional constructs prior to adolescence by using child self-report in middle childhood. Using a multi-informant approach during this stage of child development can help ascertain precursors to socioemotional difficulties and psychological outcomes such as externalizing behavior problems, anxiety and depression commonly diagnosed in adolescence.

Generalizability of these findings is limited by the small, relatively homogenous and low socioeconomic risk sample. Results from more diverse or disadvantaged populations might be different. Demographic and psychosocial-related questionnaires rely on self-report and introduce threat of reporter errors. Validity of these reports relies on accuracy of mothers and children reporting on themselves and their families and may be affected by recall bias, social desirability and the sensitive nature of some questionnaire items. Response rates could have contributed to selection bias by only capturing families who had the time and capacity to participate. In particular, the teacher-rated results must be interpreted with caution due to the small sample size of teachers. The reliance on parents/children to pass the teacher questionnaire along to the child's teacher poses a limitation. Directly contacting the teacher, via phone or email, could have allowed for follow-up and helped to increase teachers' response rates. In addition, no sociodemographic data were collected from teachers. Collecting detailed teacher (i.e., sex, age, years teaching) and classroom (i.e., classroom density, student composition) data would be beneficial to further understand how teacher reports play a role in understanding child socioemotional well-being and detangle potential biases in teacher reports, and even the consideration that some of the discrepancies might at least be in part a function of the reporters' gender and/or gender concordance/discordance between teacher and child.

It is important to note that only maternal, teacher and child-self reports were considered while evaluating multi-informant discrepancies. The use of peer report, or peer nominations, is prevalent in research surrounding social acceptance, bullying and victimization. Using peer reports to examine converging and diverging reports with child self-report can provide greater insight into children's emotional and social adjustment (Dawes et al., 2017). Peers may be in tune with aspects of children's socioemotional development that neither the parent or teacher are sensitive to such as interpersonal interactions and adjustment patterns in social settings.

6.6 Conclusions

As was seen, children reported more socioemotional problems than parents and teachers identified. What parents, teachers and external reporters may pick up on is likely only part of the whole picture. The effect of maternal distress on multi-informant reports underscores the importance of parent-child relational dynamics on child well-being and the potential confounding when reporting and detecting child behavioral and emotional problems. Still, maternal psychological distress did not solely contribute to discrepancies seen between reporters. Observability of behaviors ultimately played somewhat of a role in concordance or discordance between reporters. Establishing a strong psychosocial foundation in middle childhood is essential for future mental health and well-being.

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6.9 Tables and Figures for Manuscript 3

Table 6.1

Inter-rater correlations for Strengths and Difficulties Questionnaire (SDQ)

	Maternal-Child		Maternal-Teacher		Child-Teacher	
	n	*r*	*n*	*r*	*n*	*r*
SDQ Ratings						
Emotional Symptoms	64	.42***	47	.48***	47	.43**
Conduct Problems	64	.49***	47	.53***	47	.31*
Hyperactivity	64	.57***	47	.49***	47	.47**
Peer Problems	64	.29*	47	.52***	47	.44**
Prosocial Behaviors	64	.54***	47	.36**	47	.36*
Total Difficulties	64	.61***	47	.63***	47	.49***

Note. *$p < .05$, **$p < .01$, ***$p < .001$

Table 6.2

Maternal Psychological Distress and Maternal Strengths and Difficulties Questionnaire (SDQ) Ratings

	Maternal State Anxiety	Maternal Depressive Symptoms
Maternal SDQ Ratings		
Emotional Symptoms	.17	.35**
Conduct Problems	.22	.32**
Hyperactivity	.34**	.42***
Peer Problems	.29**	.34**
Prosocial Behaviors	-.29**	-.16
Total Difficulties	.35**	.49***

Note. *$p < .05$, **$p < .01$, ***$p < .001$

Table 6.3

Maternal Psychological Distress, Child Self-Report and Teacher Strengths and Difficulties Questionnaire (SDQ) Ratings

	Maternal State Anxiety	Maternal Depressive Symptoms
Child SDQ Ratings		
Emotional Symptoms	.07	.23
Conduct Problems	.15	.44***
Hyperactivity	.09	.27*
Peer Problems	.08	.26*
Prosocial Behaviors	-.40**	-.38**
Total Difficulties	.12	.37**
Teacher SDQ Ratings		
Emotional Symptoms	.29*	.19
Conduct Problems	.37**	.22
Hyperactivity	.30*	.22
Peer Problems	.20	.29*
Prosocial Behaviors	-.20	-.10
Total Difficulties	.38**	.30*

Note. $*p < .05$, $**p < .01$, $***p < .001$

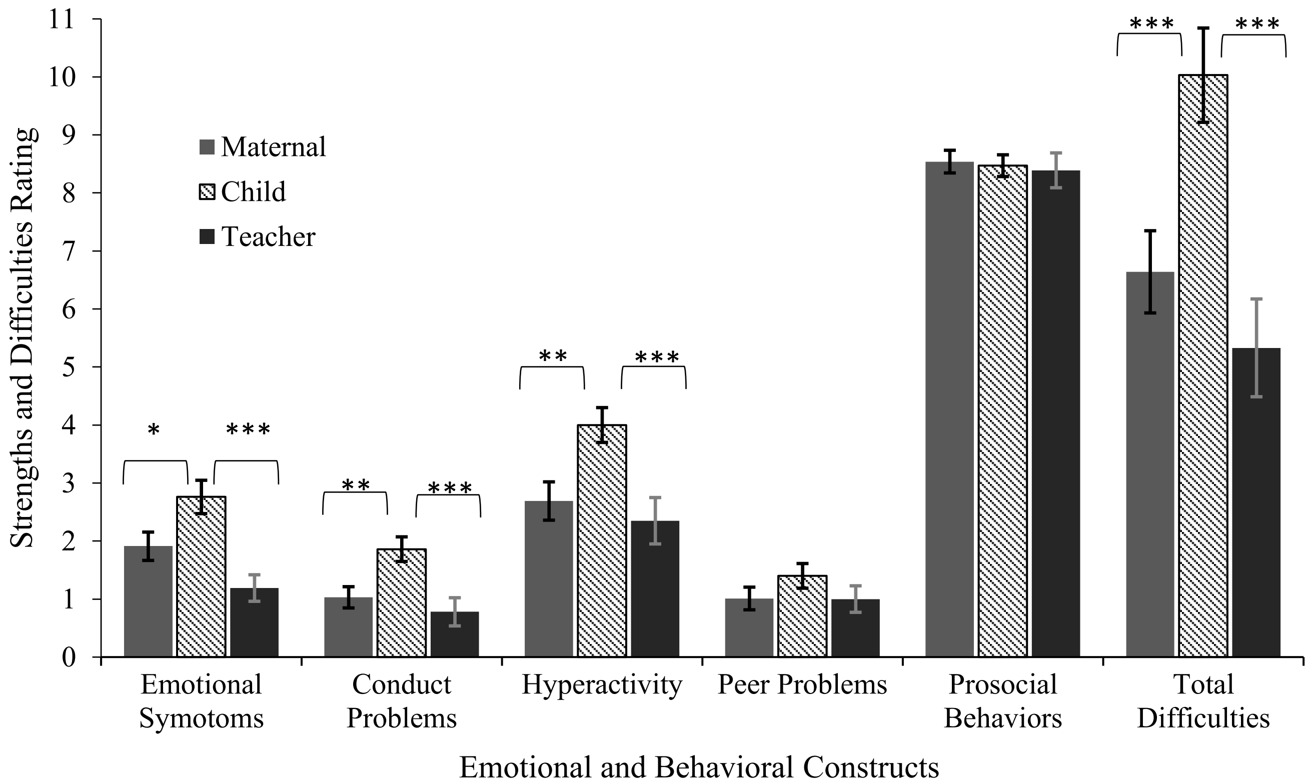

Figure 6.1. Maternal, Child and Teacher Mean Values and Differences for SDQ Ratings.

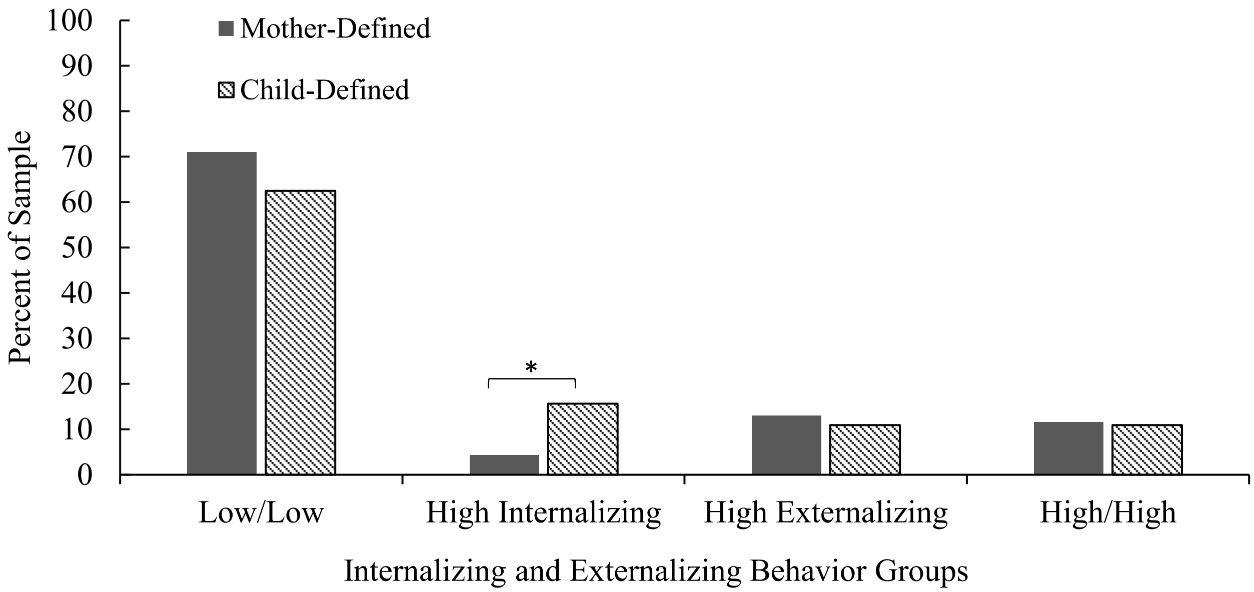

Figure 6.2. Patterns of Internalizing and Externalizing behaviors as rated by Mothers and Children

Note. * *p* <.05, ** *p* <.01, *** *p* <.001.

CHAPTER SEVEN

Conclusions and Implications of Dissertation Work

7.1 Overview of Findings

This dissertation measured processes underling inhibitory control and regulation in two distinct ways (during a laboratory-based delay of gratification task and using maternal, teacher and child self-reported questionnaires) and during two crucial developmental windows (preschool/kindergarten years and middle childhood years). The laboratory (delay) task was focused on measuring behavioral and physiological underpinnings of regulation in the presence of a challenge while the questionnaire-based assessment compared and contrasted multiple perspectives on children's emotional and behavioral regulation.

Findings from this dissertation suggest multiple concordant influences on children's regulation and socioemotional adjustment. A key uniting theme here is elucidating and adequately capturing the existing heterogeneity (or patterns) in observable and unobservable components of regulation, whether through disentangling volitional and impulsigenic behavioral processes, examining physiological regulation and reactivity, or using a multi-informant methodology including the use of children's self-report.

The findings from the manuscripts evaluating the three aims of this dissertation inform this summary. A more thorough discussion of findings, strengths and limitations can be found in chapters relating to Manuscripts 1, 2 and 3 (Chapters 4-6). Therefore, this chapter will integrate together conclusions across the three dissertation aims and briefly suggest the implications for research, programs and policies, and discuss future directions for this research work.

7.2 Conclusions, Implications and Future Directions

Regulation vs. Arousal During the Delay of Gratification Task

Self-regulatory capacity of five-year-old children was measured during the standardized Delay of Gratification task. In this task, children were given the option of either taking the immediate, lesser reward or waiting for two snack rewards. Extensive research has linked children's ability to delay gratification to a host of longitudinal outcomes, such as academic achievement, reward seeking behaviors, and socioemotional competencies into adulthood (Watts et al., 2018). There is no guarantee that the impulse to indulge in an immediate reward is the same for all children, therefore the balance between arousal and regulation was evaluated.

Children's levels of spontaneous, voluntary regulatory behaviors (e.g., fidgeting, self-talk) were examined with levels of anticipatory behaviors (e.g., continuously touching snack reward) during the delay task. Three distinct groups of children's regulatory capacity were identified (Manuscript 1): *passive* regulators, who had lower levels of regulatory behaviors (as indexed through motor activity and vocalizations) but moderate arousal (anticipation); *active* regulators who had moderate levels of regulatory behaviors (moderate motor activity and vocalizations) but high levels of arousal (anticipation); and *disruptive* regulators who had high levels regulatory behaviors (high motor activity, vocalizations) and high levels of arousal (anticipation). Almost all of the children in the *passive* and *disruptive* classes were able to delay gratification, even when adjusting for maternal, child, and sociodemographic characteristics. On the other hand, children in the *active* class had the most difficulty delaying gratification.

This work leverages and unites developmental constructs from the *dual influence* framework (volitional, or voluntary, and impulsigenic, or impulsive, processes) for inhibitory control and the Yerkes-Dodson inverted-U relationship between arousal and performance (Duckworth & Steinberg, 2015; Yerkes & Dodson, 1908). There is a dynamic relationship between voluntary, regulatory strategies and more impulsive, arousal-related processes that are implicated in children's overall self-regulatory capacity. Children with high levels of arousal, indexed through anticipation (impulsigenic pull) but insufficient volitional strategies (via motor or vocal self-regulation) were unable to delay (i.e., *active* class). Children with high levels of anticipation but employed regulatory strategies to match that level were able to delay successfully (i.e., *disruptive* class). Therefore, level of impulses (or anticipation) alone did not drive performance on the delay task.

Physiologic correlates of regulatory strategies were used to further disentangle the dynamic relationship between arousal and regulation (Manuscript 2). The autonomic nervous system (ANS) works to maintain a state of physiological homeostasis through two branches: parasympathetic (responsible for "rest and digest") and sympathetic (activated for "fight or flight" responses). The ANS is interconnected with limbic brain systems that facilitate the way physical, environmental and social experiences shape emotional and behavioral outcomes (Mulkey & du Plessis, 2019). The ANS reflects arousal vs. regulation processes by detecting stressor/challenges, increasing arousal to adequately respond to the challenge, then down regulating to return to pre-stressor/challenge state. Children's balancing acts between physiological arousal and regulation were revealed when examining heart rate and respiratory sinus arrhythmia (RSA) reactivity during the delay of gratification task.

A central finding here was that children who successfully delayed gratification had less of an increase in heart rate and more of a decrease in RSA from the start of the delay task to the end of the task, as compared to children who did not delay. Methodologically, this finding indicated that analyzing overall pre-task to task differences, as typically encountered in the literature, might miss nuanced physiological variation contributing to children's delay ability. Efficient suppression of vagal tone is necessary when attention is required for coping with environmental demands, in this case, delaying gratification. Suppression in vagal tone results in a decrease in RSA (and coupled with increases in heart rate) in response to a challenge (Coulombe et al., 2019; Hinnant & El-Sheikh, 2009; Porges et al., 2007). Therefore, the association between heart rate and RSA reactivity during the task and children's successful delay of gratification is likely an indicator of effective of vagal tone suppression.

Heart rate and RSA reactivity over the course of the delay task was also concurrently related to behavioral regulatory and anticipation-related arousal (Manuscript 2). Heart rate and RSA reactivity during the task independently moderated the relationship between children's regulatory class and delay ability, however, when examined together RSA reactivity during the task remained as a significant moderator. Children in the *active* class with increasing RSA for the task duration, indicative of vagal control, were more likely to delay as compared to children with decreased RSA decreased during the task period. These results are supported by the existing evidence base pointing to effective vagal suppression aiding inhibitory control and delay ability (Hinnant & El-Sheikh, 2009; Holochwost et al., 2018; Holzman & Bridgett, 2017). Unique here are the findings related to inhibitory control classes. Children modulated their physiological arousal were able to delay successfully, even when voluntary regulatory behaviors (motor and vocal regulation) were not effective.

A closer look at patterns of children's heart rate and RSA during the delay task indicated some physiological disruption in the group of children who did not delay as compared to children who did delay. Although there were no significant findings when examining epoch by epoch mean values of heart rate and RSA during the task, children who delayed the full task time had physiologic patterning that is considered typical in response to a challenge, while children who were unable to delay exhibited large epoch by epoch fluctuations in both heart rate and RSA during the task (Figures 5.1 and 5.2). These differences in patterns may indicate the differentially taxing nature of the delay task for some children, who eventually did not successfully delay. The patterns seen may also reflect the balance between levels of anticipation towards the snack reward over the course of the task and physiological modulation to regulate (or not regulate, in the case of children who were unable to delay) such anticipation to complete the task at hand. Though the sample size of children who did not delay in this study is too small to effectively detect differences in differential autonomic susceptibility, implications of observed visual differences are worth consideration.

Children whose BMI indicated that they were obese or overweight struggled to delay the full task time as compared to children who were underweight/normal weight. In Manuscript 1, this relationship was attenuated once accounting for sociodemographic and behavioral covariates. Manuscript 2, on the other hand, showed clear and consistent associations between children's BMI and delay ability, even after adjusting for sociodemographic, behavioral and physiological covariates. The association between BMI and delay ability might be due to the delay task using a snack-related reward and therefore the reward itself, regardless of quantity, produced differential levels of anticipation. Some research has shown that that effective early self-regulation strategies (e.g., turning to face away from reward), during delay of gratification tasks not only enabled children to wait longer, but also was similar to eating-regulation strategies that children used to lower arousal to food, resulting in lower levels of obesity later in childhood (Power et al., 2016). The relationship between regulation strategies and BMI control may be reciprocal in nature. There were no differences in children's BMI by latent self-regulatory class detected in Manuscripts 1 or 2, therefore conclusions around why controlling for physiological regulation revealed associations between delay ability and child BMI that were otherwise masked when examining behavior alone are speculative.

Results from Manuscripts 1 and 2 support examining the internal tug-of-war that manifests in behaviorally heterogeneous manners to inform programs and interventions aimed at reducing impulsive and disruptive behaviors. To date, researchers have focused on understanding, describing and training voluntary processes underlying children's regulation capacity (Corriveau et al., 2016; Duckworth & Steinberg, 2015; Neuenschwander & Blair, 2017; Prinz, 2019). The goal has been to examine voluntary processes as a proxy measure for impulsiveness. However, both voluntary and impulsigenic processes contribute to socioemotional adjustment. Less adaptive self-regulation strategies to cope with or modulate level of impulsiveness has been linked to internalizing and externalizing problems and conduct/adjustment issues (Eisenberg et al., 2004; Lengua, 2002).

These results have implications for school-based interventions aimed at improving self-regulation capacity. Various interventions targeting cognitive, socioemotional or an integrated cognitive and socioemotional regulation have been established (Gagne & Nwadinobi, 2018). However, there is limited focus on disaggregating various components of inhibitory control from measurement and program/intervention perspectives. For children who are high on impulsigenic pull but have inadequate strategies to manage it, incorporating active breaks (sometimes referred to as "wiggle breaks") in classrooms could be beneficial for attenuating arousal. The integration of brief activity breaks during classroom instruction has demonstrated benefits to a host of proximal and longitudinal learning-related outcomes as well (Norris et al., 2015). Differentiating patterns of regulation strategies, whether it be through self-talk/distraction, fidgeting as a form of arousal control, or a combination, and their relation to arousal/impulse regulation can provide key insights into how children self-regulate.

This work also has implications for policies and practices surrounding school discipline and behavior management. Many schools have adopted social and emotional learning programs that have been shown to benefit children's mental health, academic achievement and emotional/behavioral outcomes (Durlak et al., 2011; Goldberg et al., 2019). However, following education reform, notably the No Child Left Behind Act focusing on high-stakes of standardized testing and academic output, classroom policies surrounding behavior management reverted to a "no excuse" or "zero tolerance" method (Bailey et al., 2019). Such shifts in classroom culture resulted in reactive and exclusionary discipline policies that limit children's ability to build and practice self-regulation skills (Bailey et al., 2019); children who were unable to self-regulate were more likely to face disciplinary removals, rather than support to manage behavior effectively.

The current findings support differential mechanisms by which children regulate, including a range of behaviors more typically seen as disruptive, such as constant self-talk and fidgeting, and the influence of physiological processes modulating arousal. Although the role of inhibitory control processes on classroom disciplinary actions was not examined, the findings here provide leverage for future research to examine the pathways in which different components of self-regulation affect school discipline outcomes. Observational and psychophysiological methods can be effective tools for parsing out self-regulatory processes underlying delay of gratification and inhibitory control. Aggregating existing audio/video data across studies that have utilized this standardized delay task may be one way to generate a sample that reflects population-level sociodemographic compositions in which to replicate study findings.

Sex Differences in Regulation

Sex differences in regulation were found across all three studies included in this dissertation. Findings from Manuscripts 1 and 2 both revealed sex differences in delay ability, such that girls were more likely to delay the full task time than boys. In fact, 9 out of the 11 children who ate the snack reward right away, and therefore did not have any usable regulation strategy or physiological data, were boys. When examining physiological arousal, girls had higher RSA before the delay task than boys did (Manuscript 2). A high basal RSA, indicative of a vagal “brake”, is key to maintaining physiological homeostasis (Coulombe et al., 2019; Hinnant & El-Sheikh, 2009; Porges et al., 2007), and therefore girls in this sample could have been physiologically better prepared to respond to the delay task. Differences in physiological arousal modulation, therefore, may be contributory to sex differences in delay ability seen in this study.

Results from Manuscript 1 indicated that boys tended toward higher levels of motor activity as compared to girls during the delay task, even after controlling for maternal, family and other characteristics such as child BMI. There were no other sex differences in regulatory strategies used. The findings on sex differences in motor activity levels, coupled with physiological arousal before the delay task, relate to the larger literature base on sex differences on presentation and diagnosis of motor activity-related difficulties, such as attention deficit hyperactivity disorder (ADHD) and impulsivity (Slobodin & Davidovitch, 2019). Motor behaviors and levels of anticipation may manifest in a sex-dependent manner with implications for later behavioral and emotional difficulties, but this warrants further investigation.

Interestingly, Manuscript 3 revealed sex differences in teacher reports. Overall, teachers reported boys as having more difficulties as compared to girls and specifically reported boys having more difficulties with hyperactivity and inattention as compared to girls. It is possible that sex differences in behavioral and physiological regulation, as observed during the delay of gratification task (Manuscripts 1 and 2), could be early indicators of sex differences in later emotional and behavioral difficulties as teachers identified in the classroom. Though this dissertation did not link the delay of gratification task studies with the questionnaire-based assessment in middle childhood, teachers may be reporting on what is dually recognizable through early laboratory-based tasks. This is speculative in nature but starts to address the versatility of using multiple methods of assessment to characterize regulation.

Family and Social Environment

Results across all three studies generally indicated no differences in children's physiological, behavioral and emotional regulation by their family's socioeconomic composition. Maternal age, however was a consistent predictor of children's delay ability in Manuscript 1, but was not related to children's delay ability in Manuscript 2. Some studies have examined the role of maternal age on children's self-regulatory capacity, indicating younger motherhood as a risk factor for lower levels of child regulation development (Jusiene et al., 2015; Ng-Knight & Schoon, 2017). The association between maternal age and children's regulation in Manuscript 1 may reflect a larger picture of unmeasured social risk relating contributing to early childhood adversity that is beyond the scope of these studies.

Sensitive and responsive parenting has been shown to relate to children's patterns of autonomic regulation that are considered healthy and normative (i.e. high baseline RSA and RSA changes in response to stimuli) (Perry et al., 2014). As a result, interventions have been targeted at the family level for increasing parental sensitivity in order to support healthy autonomic regulation in children starting as early infancy. Promoting sensitive parenting and caregiving in infancy and early childhood may not only have lasting impacts on children's autonomic regulation, but also on the quality of parent-child relationships over time. Although Manuscript 2 found no associations between autonomic regulation and maternal psychological distress, the importance of parenting/caregiving in children's development should be noted.

Maternal depressive and anxiety symptoms as risk factors for child emotional and behavioral difficulties are well-researched topics (Goodman et al., 2011; Herba et al., 2013; Monti & Rudolph, 2017). There were no discernable differences in children's delay ability, self-regulatory strategies or physiological regulation by maternal psychological distress in Manuscripts 1 and 2. However, maternal psychological distress played a persistent role when examining maternal, teacher and child self-reports of difficulties with emotional and behavioral regulation in Manuscript 3. Women who reported having more psychological distress also reported their children as having more emotional and behavioral difficulties and children whose mothers had higher psychological distress reported having more difficulties themselves. Teachers also rated children as having more behavioral and emotional problems if the child's mother had higher psychological distress. Although teachers are likely not directly impacted by maternal psychological distress, teachers serve as an important external observer to report on children's regulation in a structured setting. Teachers, therefore, provided validation for the findings related to maternal psychological distress and children's well-being.

There are multiple pathways by which maternal psychological distress acts on children's socioemotional development. One pathway is in the shared genetic variance between mothers and their offspring; children of mothers who have depressive symptoms or anxiety have higher propensities for developing depression and anxiety themselves (Axelson & Birmaher, 2001). Another pathway is through parent-child interactions/relationships (De Los Reyes &

Ohannessian, 2016; Van Roy et al., 2010). More distressed women may interact with their children differently as compared to less distressed women, thus affecting the quality of caregiver interactions that has been implicated in development of children's socioemotional adjustment (Dubois-Comtois et al., 2013). The current study design did not provide leverage to examine the multiple pathways through which maternal psychological distress may affect children's reports of higher emotional and behavioral problems.

Measurement of Internal States using Children's Self-Report

It is important to note here is that observed or laboratory-based methods showed no effects of maternal psychological distress on children's regulation, as evidenced by findings in Manuscript 1 and 2. However, children's self-perceptions were largely influenced by maternal psychosocial distress when assessed through questionnaire-based methods (Manuscript 3). This finding, in tandem with the key finding from Manuscript 3 indicating that children reported more difficulties with emotional and behavioral regulation than parents and teachers reports starts to implicate the crucial role of utilizing children's self-report. Mothers characterized their children as having significantly fewer difficulties, specifically internalizing problems (i.e., emotional problems) as compared to children's self-perceptions.

Much of children's internal struggles may be beyond parents'/caregivers' visibility, thus, underscoring the importance of child self-report in early developmental periods. This is important to consider when designing screening tools and considering who to ask to best capture underlying and early precursors to later mental health problems. The results from Manuscript 3 underscore that children as young as age 8 can identify salient emotional and behavioral problems, and should be considered an active voice in measurement of socioemotional development. National policies, including guidelines of the American Academy of Pediatrics, have continuously advocated for including children's perspectives in research and practice (AAP, 2012; Deighton et al., 2014; Greco et al., 2016), yet there are no clear guidelines as to how child self-reports should be implemented in clinical practice (Kaurin et al., 2016). Mobilizing this conversation to the forefront of socioemotional monitoring will be key to bolstering accurate and early risk factor assessment. The integration of multi-informant reports when monitoring child socioemotional development remains unclear and more understanding is needed to reliably incorporate the child perspective. Incorporating child self-report as a part of clinical practice/well child visits, school behavior screenings, for example, especially in developmental periods characterized by transitions such as middle childhood, is key to evaluate behavioral and emotional difficulties.

7.3 Concluding Remarks

The translation of developmental research into programs, policies and interventions drives the process for turning scientific inquiry into public health action. The work included in this dissertation expands on existing measurement and methodological tools used to discern patterns in regulation and socioemotional development. This work leveraged multiple modes of data including observational, physiological and questionnaire-based measures. Although it did not include a longitudinal analysis from early to middle childhood, important regulation and developmental constructs were analyzed during key transition periods. Advancing this work can help identify multi-level barriers to effective socioemotional development including the effect of social and built environments and family dynamics. Given the importance of positive childhood socioemotional development, substantial investments should be made to adequately identify, evaluate and support the healthy development of children.

7.4 References

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CURRICULUM VITAE

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EDUCATION

PhD, Maternal, Fetal & Perinatal Health **Sept 2020**
Department of Population, Family and Reproductive Health (PFRH)
Johns Hopkins Bloomberg School of Public Health, Baltimore, MD

- *Dissertation:* Patterns of Inhibitory Control and Socioemotional Development: A Multimodal Examination in Early and Middle Childhood
- *Advisor:* Dr. Janet DiPietro, PhD, Vice Dean for Research and Faculty & Department of Population, Family and Reproductive Health

MSPH, Child Health & Development **May 2016**
Department of Population, Family and Reproductive Health (PFRH)
Johns Hopkins Bloomberg School of Public Health, Baltimore, MD

- *Master's Thesis:* Maternal prenatal salivary diurnal cortisol: Associations with infant negative affect during Face-to-Face Still-Face paradigm as rated by observers.
- Certificate in Maternal and Child Health (2015)

BS, Neuroscience**; minor** Sociocultural Anthropology **May 2014**
College of Literature, Science and Arts
University of Michigan, Ann Arbor, MI

SUMMARY OF RESEARCH SKILLS

Research methodology & design * primary data collection on children & families (lab, in-home, school) * psychosocial, developmental & biomeasure data collection * statistical analyses (Stata, SPSS, MPlus) * online survey programming (REDCap, Qualtrics) * behavioral coding * research team management* data management * project management *

RESEARCH INTERESTS

Child behavioral development * child mental health & well-being * school-related outcomes * social & environmental risk factors * maternal mental health * maternal health* statistical methods for developmental science * research dissemination & translation

AWARDS, HONORS & GRANTS

- **Maternal and Child Health Training Grant**, full doctoral tuition scholarship, Health Resources and Services Administration (HRSA); 2016-2020
- **Donald A. Cornely Scholar**, Johns Hopkins Bloomberg School of Public Health (JHSPH) PFRH, merit-based award: 2019-2020
- **Bernard and Jane Guyer Scholarship Fund**, JHSPH PFRH, stipend for dissertation research: 2018-2019
- **Master's merit-based tuition scholarship**, JHSPH PFRH; 2015-2016
- **University Honors,** College of Literature Science and Arts, University of Michigan; 2013-2014

RESEARCH EXPERIENCE

Dissertation Research **Jan 2019 – Aug 2020**
Johns Hopkins Bloomberg School of Public Health, Baltimore, MD

- Independently designed and conducted a follow-up study of 118 families from two cohorts of a 25-year longitudinal study (Fetal Neurobehavioral Development)
- Developed and administered REDCap online questionnaires using validated instruments to capture

maternal, child self-report and teacher report of child socioemotional development
- Collected, managed, and analyzed data using analysis of variance, regression and descriptive analyses
- Developed/adapted behavioral coding schemes for motor, vocal and anticipatory self-regulation during Delay of Gratification Task using data from prior waves of data collection
- Applying latent variable analyses to Delay of Gratification data

Graduate Research Assistant **Apr 2019 - Present**
Baltimore Generations Project (B'more Gen), Baltimore, MD
- Collecting, managing and analyzing longitudinal intergenerational behavioral and biomeasure data on families and children aged 4-13 years in Baltimore City
- Supervising 8 undergraduate research assistants in data collection and leading bi-weekly lab meetings
- Assisting with project management: scheduling participants, lab protocols, and data quality/integrity
- Conducting advanced statistical analyses and supporting manuscript preparation
- Created Qualtrics online questionnaires and NIH Toolbox batteries to collect data from parents, children, co-parents and teachers
- Developed Stata coding for questionnaire scoring and multi-informant database management

Graduate Research Assistant & Student Investigator **Jun 2015 - Present**
Fetal Neurobehavioral Unit, Johns Hopkins Hospitals, Baltimore, MD
- Analyzing maternal and fetal physiological data with multilevel mixed-effects models
- Supporting multiple manuscript preparations
- Collected primary data for measures of maternal and fetal heart rate and sympathetic nervous system activation
- Transitioned maternal psychosocial and sleep questionnaires to REDCap from paper version

Research Consultant **Oct 2018 - Mar 2019**
Baltimore Hunger Project; Baltimore, MD
- Designed impact evaluation surrounding link between hunger and child development, academic outcomes, and behavioral health in Baltimore City
- Contributed to grant writing and fundamental aspects of study design and data collection

Graduate Research Assistant **Jun 2015 - May 2016**
Johns Hopkins Bloomberg School of Public Health; Baltimore, MD
- Collected behavior and biomeasure self-regulation data from mothers and children aged 5 years through home visits to extend longitudinal study (Prenatal Indicators of Self-Regulation)
- Supervised 4 undergraduate research assistants on behavioral coding
- Lead weekly lab meetings to discuss lab protocol issues/questions and data integrity
- Presented longitudinal data at International Congress of Infant Studies (2016)

Graduate Research Assistant **Jun 2015 - May 2016**
Fetal Neurobehavioral Unit, Johns Hopkins Hospitals; Baltimore, MD
- Conducted stimulus-pairing protocol to determine whether a near-term human fetus displays associative learning to auditory stimuli
- Monitored fetal heart rate in response to maternal postural adjustments
- Recruited participants from Maternal Fetal Medicine clinic

Data Analyst **Jun 2015 - May 2016**
Neuroscience Intensive Care Nursery, Johns Hopkins Children's Center; Baltimore, MD
- Consulted on study design and statistical analyses for assessing the effect of perinatal maternal/infant infection on neurodevelopment in very low birth weight, preterm infants
- Conducted advanced data analysis and wrote methods/results sections of manuscripts
- Co-authored 2 manuscripts published in *American Journal of Obstetrics and Gynecology* and *Journal of Perinatology*

Student Investigator **Jan 2015 - Jun 2015**

Nutrition in Pregnancy Clinic, Johns Hopkins Hospitals; Baltimore, MD
- Derived qualitative data to explore effectiveness of a multi-disciplinary clinic for obese, pregnant women through semi-structured, one-on-one interviews with patients and clinicians
- Developed literature search strategies and reviewed literature for prenatal interventions for high-risk obstetric populations that addresses infant outcomes

Data Analyst & Student Investigator **Dec 2014 - Jun 2015**
Johns Hopkins Bloomberg School of Public Health; Baltimore, MD
- Analyzed infant morbidity, anthropomorphic data and incidence of respiratory infections in a sample of 4,000 mothers and children in Nepal using generalized equation modeling for manuscript

Graduate Research Assistant **Oct 2014 - May 2015**
Harriet Lane Clinic, Johns Hopkins Children's Center, Baltimore, MD
- Collected primary language development data in low-income families in Baltimore City using a novel language analysis device (LENA)
- Administered standardized vocabulary and communication development tasks to mothers and children
- Conducted preliminary analyses to assess risk factors of child language delay

Undergraduate Research Assistant & Student Investigator **May 2011 - Aug 2015**
Veteran Affairs Hospital, Ann Arbor, MI
- Conducted a retrospective study with information from electronic medical records and PET scans in a Veteran population of lung cancer patients
- Applied survival analyses and mixed-effects regression modeling
- Prepared and submitted a first authored manuscript in *American Journal of Clinical Oncology*

Undergraduate Research Assistant **Jan 2014 - May 2014**
Michigan Longitudinal Study Lab, Ann Arbor, MI
- Supported an initiative assess how early childhood behaviors, genetics and brain mechanisms serve as predictors of adult onset alcoholism
- Assisted with data entry, database organization and data management
- Developed SPSS code for questionnaire scoring

Undergraduate Research Assistant **Sept 2010 - May 2011**
Department of Pediatrics, Taubman Health Center, Ann Arbor, MI
- Evaluated online medical records and health related quality of life surveys to assess the adherence to medications and transition readiness skills in pediatric liver transplant patients
- Designed and co-led web-based interventions and focus groups for adolescents who were pediatric liver transplant patients
- Orally presented findings at University of Michigan UROP Poster Symposium (2011)

TEACHING EXPERIENCE

Guest Lecture to Graduate Students
PH. 380.642.81: Child Health and Development **Oct 2019**
Johns Hopkins Bloomberg School of Public Health, Baltimore, MD
Lecture Title: Siblings' Impact on Child Development

Teaching Assistant for Graduate Students
PH. 380.642.81: Child Health and Development **Oct 2019 - Dec 2019**
Johns Hopkins Bloomberg School of Public Health, Baltimore, MD **Oct 2017 - Dec 2017**
Drs. Kristin Voegtline, Robert Blum, and Michael Blum

PH. 380.604.01: Life Course Perspectives on Health **Aug 2016 - Oct 2016**
Johns Hopkins Bloomberg School of Public Health, Baltimore, MD **Aug 2017 - Oct 2017**
Drs. Robert Blum and Mary Elizabeth Hughes

PH. 380.611.01: Fundamentals of Program Evaluation **Jan 2016 - Mar 2018**

Johns Hopkins Bloomberg School of Public Health, Baltimore, MD
Dr. Kristin Mmari

LEADERSHIP EXPERIENCE

Doctoral Admissions Committee Member **Dec 2017 - Present**
Johns Hopkins Bloomberg School of Public Health; Baltimore, MD
- Evaluating incoming doctoral student applications with a team of faculty members
- Assisting with admission decisions and interviewing doctoral student applicants

JHSPH Academic Ethics Board **Jun 2017 - Present**
Johns Hopkins Bloomberg School of Public Health; Baltimore, MD
- Student member on the school-wide Academic Ethics Board and individual academic ethics hearing panels
- Attending academic ethics hearings and making decisions to resolve accusations

President of Department Student Association **Jun 2016 - Jun 2017**
Johns Hopkins Bloomberg School of Public Health; Baltimore, MD
- Doctoral Student representative for PFRH department
- Organized seminars, professional development workshops, and social activities for student body morale
- Department liaison for relaying student questions and issues to chair of PFRH department, faculty and staff

PUBLICATIONS AND PRESENTATIONS

Peer-Reviewed Publications

Tsimis, M., Johnson, C., **Raghunathan, R**., Northington, F., Burd, I. and E. Graham. September 2015. Risk Factors for Periventricular White Matter Injury in Very Low Birth Weight Neonates, *American Journal of Obstetrics and Gynecology* (doi:10.1016/j.ajog.2015.09.108).

Johnson, C., Burd, I., **Raghunathan, R.**, Northington, F. and E. Graham. October 2015. The effect of Perinatal Inflammation/Infection on Metabolic Acidosis in Hypoxic-Ischemic Encephalopathy. *Journal of Perinatology* (doi: 10.1038/jp.2015.221).

Raghunathan, R., Cease, K., Troeschel, S., Zhao, L., Gross, M., Chen, G., Chopra, V. and N. Ramnath. August 2015. Impact of Staging with Positron Emission Tomography (PET) on Management and Survival of American Veterans with Stage I-III Non-Small Cell Lung Cancer. *American Journal of Clinical Oncology (doi:* 10.1097/COC.0000000000000316).

Manuscripts Under Review

DiPietro, J., **Raghunathan, RS.,** Watson, H., Bai, J., Sgambati, F., Henderson, J., Pien, G. July 2020. The Fetal Heart Rate Response to Sleep. (under review at *Developmental Science*).

Presentations (Oral and Poster)

Raghunathan, R., Voegtline, K. and J. DiPietro. Maternal Prenatal Salivary Diurnal Cortisol: Associations with Infant Fussiness and Rated by Observers and Mothers [abstract]. In: International Conference on Infant Studies; 2016 May 25-26; New Orleans, LA (accepted).

Voegtline, K. **Raghunathan, R.,** Moore, G. and J. DiPietro. [abstract]. Fetal Origins of Infant Emotional Reactivity. In: International Conference on Infant Studies; 2016 May 25-26; New Orleans, LA (accepted).

Raghunathan, R., Dore-Sites, D., Lopez, J. and E. Fredericks. Adherence to Medications and Transition Readiness Skills in Pediatric Liver Transplant Patients [oral presentation]. In: Undergraduate Research Opportunities (UROP) Poster Symposium; 2011 May; Ann Arbor, MI.

Acknowledged Contributions

Gregory, E. F., Goldshore, M. A., Showell, N. N., Genies, M. C., Harding, M. E., & Henderson, J. L. (2017). Parent and Clinician Perspectives on Sustained Behavior Change after a Prenatal Obesity Program: A Qualitative Study. *Childhood obesity (Print)*, *13*(2), 85–92. https://doi.org/10.1089/chi.2016.0149

Katz, J., Englund, J. A., Steinhoff, M. C., Khatry, S. K., Shrestha, L., Kuypers, J., Mullany, L. C., Chu, H. Y., LeClerq, S. C., Kozuki, N., & Tielsch, J. M. (2017). Nutritional status of infants at six months of age following maternal influenza immunization: A randomized placebo-controlled trial in rural Nepal. *Vaccine*, *35*(48 Pt B), 6743–6750. https://doi.org/10.1016/j.vaccine.2017.09.095

Fredericks, E., Dore-Stites, D., Calderon, Y., Well, A., Eder, J., Magee, C., and Lopez, J. (2012). The Relationship between Sleep Problems and Health Related Quality of Life among Pediatric Liver Transplant Recipients. *Liver Transplantation*, *18*(6), 707–715.

PROFESSIONAL AFFILIATIONS

Member, American Public Health Association **Jan 2019**

- Abstract Reviewer: Maternal and Child Health, Mental Health sections
- Student Assembly Member

Member, International Congress on Infant Studies **Jan 2016**

COMMUNITY SERVICE AND OTHER ACTIVITIES

School Visit and Programming Team, Science Outside the Lines **Sept 2017 - Present**

- Partnering with community organizations and Baltimore City Schools to promote STEM and interactive science-based learning through school visits and demonstrations about the brain

Community Consultant, Clay Pots **Mar 2018 - Jul 2018**

- Conducted a needs assessment of a community-based GED preparatory program and Coffeehouse program for West Baltimore residents

Volunteer*,* SOURCE (Student Outreach Resource Center) **Oct 2014 - May 2016**

- Assisted local Baltimore City organizations (Project Homeless Connect, Real Food Farm, Civic Works)

Fellow and Volunteer, Child Family Health International; La Paz, Bolivia **June - July 2013**

- Volunteered at 3 pediatric hospitals in La Paz, Bolivia
- Worked at a local health fair with local clinicians to educate mothers about infant nutrition

Volunteer Teacher and Youth Leader*,* Chinmaya Mission Avantika; Ann Arbor, MI **Sept 2009 - May 2014**

- Taught 1st and 2nd graders about Hinduism and Indian culture using interactive activities